REFRACTION

A SIMPLE AND CONCISE TREATISE
ON PRACTICAL SIGHT-TESTING

(ILLUSTRATED)

GUY E. DRUIFF

REFRACTION,

A SIMPLE AND CONCISE TREATISE ON PRACTICAL SIGHT-TESTING.

BY

GUY E. DRUIFF.

WITH 150 CUTS AND DIAGRAMS.

PUBLISHED BY

ANGLO-AMERICAN OPTICAL COMPANY,

47, HATTON GARDEN, LONDON, E.C.

1911.

TO THOSE

FROM WHOM I OBTAINED MY KNOWLEDGE

THIS BOOK IS DEDICATED,

IN GRATEFUL RECOLLECTION OF THEIR

INVALUABLE TEACHINGS.

PREFACE.

THERE is probably no published work on Practical Sight-Testing, which has avoided the encumbrance of too much unexplained technical language, without at the same time losing the accuracy and definiteness of scientific precision. The author has aimed never to use a long word when a short one is as good; and never to employ a short word when a longer one is better.

Then, believing that even perfect rules lose much of their value if their reasons are unknown, he has sought to give all needful scientific information as to the anatomy and physiology of the eyes; as to the laws of refraction, and the action of prisms and lenses; and then as to the conditions of perfect and imperfect focussing and accommodation.

This review of fundamental facts and laws, has rendered it possible to give practical directions for the use of the refractionist's manifold resources for the discovery, measurement, relief, and, where possible, the cure of the several natural ills that the eyes are heirs to.

It is hoped, therefore, that he who uses this guide will find that the procedure recommended is scientifically deduced, clearly stated, and so far repeated as to secure that readiness and accuracy of recollection which is the natural effect of due repetition:—"*Memoriæ genetrix iteratio.*"

There is, perhaps, little occasion for any reference to particular subjects; but it may be well to point out that the

chapter on Transposition is quite new to the practical literature of the subject, and will enable the operator to supply, not what "will be well enough," but absolutely the best and most elegant remedy for each specific infirmity of vision.

The chapters on Retinoscopy and Ophthalmometry will be valued; the collection of Cases will give invaluable illustrations of principles and practice; and the Glossary which is superadded to the lucid explanations contained in the text will do away with all the difficulty which sometimes attaches to the use of accurate technical terms.

Finally, it has often been the reproach of untaught refractionists, that they so readily betake themselves to the use of potent drugs, atropine, and others. This work will, it is believed, show a more excellent way, and will enable the careful refractionist to do his work not only as well, but even far better, without cycloplegics than with them.

PREFACE TO THE FIFTH EDITION.

It is, indeed, most gratifying that another Edition of this work should be required so soon after the appearance of the last.

Although the bulk of this book has necessarily increased very considerably since the earlier editions, the original idea has been rigidly adhered to ; so that the character of the work has lost none of its conciseness or simplicity of explanation.

The increasing demand for the book fully justifies the belief that "Refraction" will eventually find its way into the library of all those interested in the science of Visual Optics and Sight-Testing.

CONTENTS.

ABBREVIATIONS.

Ac.	Accommodation.
æt.	Age.
Am.	Ametropia.
Amp. ac.	Amplitude of accommodation.
An.	Anisometropia.
As.	Astigmatism.
Asth.	Asthenopia.
Av. ac.	Available accommodation.
ax.	Axis.
B.E.	Both eyes.
Cc. or −	Concave.
Cx. or +	Convex.
cm.	Centimetre.
Cv.	Convergence.
cyl. or C.	Cylinder.
D.	Dioptre.
D.T.	Distance test.
D. cx.	Double convex.
D. cc.	Double concave.
E. or Em	Emmetropia.
H. or Hy.	Hypermetropia.
Ha.	Absolute Hypermetropia.
Hl.	Latent Hypermetropia.
Hf.	Facultative Hypermetropia.
Hm.	Manifest Hypermetropia.
Hr.	Relative Hypermetropia.
J.	Jaeger.
L. or L.E.	Left eye.
M.A.	Metre angle.
M.	Metre.
mm.	Millimetre.
My.	Myopia.
N.T.	Near test.
N.V.	Normal vision.
O.D.	Oculus dexter, or R.E.
O.S.	Oculus sinister, or L.E.
O.U.	Oculi uniti, or both eyes together.
Pb.	Presbyopia.
P. cc.	Peris concave.
P. cx.	,, convex.
P.D.	Inter-pupillary distance.
pl.	Plano.
P.P.	Near point (punctum proximum).
P.R.	Far point (punctum remotum).
R. or R.E.	Right eye.
℞.	Recipe, prescription.
S. or sph.	Spherical.
Sn.	Snellen.
Stb.	Strabismus.
Tp.	Type.
V.	Vision.
V.A.	Visual acuity.

SIGNS.

−	concave.
+	convex.
⌒	combined with.
┌	,, ,, at right angles.
c̄	cum (with).
°	degree (refracting angle).
°D	degree of deviation.
Δ	prism-dioptre.
∇	centrad.
′	foot or minute.
″	inch or second.
=	equal to.
∞	Infinity: 20 feet or over.
μ	refractive index.

REFRACTION.

CHAPTER I.

ANATOMY.

The eyeball, or organ of vision, is a complete optical apparatus situated in the bony cavity of the orbit, in which situation it is securely protected from injury, whilst it possesses the most extensive range of vision.

It is acted upon by several muscles, by which it is capable of being directed to any desired point; it is also supplied with vessels and nerves, and additionally protected in front by many appendages, such as the eyebrows, lids, lashes, etc.

The eyeball in shape is almost spherical, with an additional segment of a smaller sphere engrafted on the anterior portion; the total length, and also its vertical diameter, measures almost twenty-three twenty-fifths of an inch; transversely, the globe is rather more than this, measuring just about an inch. It is made up of three coats or layers; and within these coats are contained three humours, which, together with the Cornea, constitute what are known as the "refractive media" of the eye, the function of which is to focus rays from external objects clearly and distinctly on the Retina, or

sensitive expansion of the Optic Nerve; whence the sensation produced is transmitted to the centre in the brain where consciousness of the impression arises. This recognition is termed "sight"; the seat of vision being therefore in the brain, and not in the eye itself.

The coats or layers from without, inward, are:—

1. Sclerotic and Cornea.
2. Choroid, Iris, and the Ciliary body.
3. Retina.

The Sclerotic, or outer coat (which is commonly known, from its white appearance, as the "white of the eye"), forms the posterior five-sixths of the eyeball; it is a firm, unyielding, fibrous membrane, formed for protecting and maintaining the shape of the globe, and is much thicker behind than in front. The insertion of the muscles which govern the movements of the eye is in this coat.

Continuous with the Sclerotic anteriorly, and occupying the remaining one-sixth of the outer covering of the globe, is a transparent membrane, known as the Cornea, forming a window through which rays of light enter the interior of the eye. The attachment of the Cornea to the Sclerotic is called the Sclero-corneal junction; at this line of union the two coats form a slightly concave furrow, which shape gives to the globe an added firmness. The Cornea contains no blood vessels, but is supplied with nerves; and is perfectly transparent in the healthy state. The curvature of the Cornea varies at different periods of life, becoming less convex as the individual advances in age. The average radius of curvature is about 8 m/m (actually 7·8 m/m) horizontally, and in the vertical direction somewhat less than this; thus the corneal surface is not truly spherical, but has a slight Astigmatism, the direction of shortest radius being vertical. (This explains why a weak convex cylinder, axis at 90°, is nearly always accepted in preference to one with the axis in the horizontal). In order to

SECTION THROUGH THE SCLEROTIC, CORNEA, IRIS, AND CRYSTALLINE LENS.

Photographed from Nature by Mr. W. Green, showing the relation of these several parts. The Ciliary muscle can be seen very distinctly, together with the fibres of the suspensory ligament; the Ciliary processes, although somewhat broken, are also shown. The sphincter muscle of the Iris is seen as a dark band near the inner pigmented margin of the Iris.

see the Iris it is necessary to look through this coat, which on account of its transparency is almost invisible, except when looking at it from the side; but notwithstanding its transparency, it is a tough, unyielding membrane—hence its name "Cornea," which means "horny." Although its appearance gives the impression of extreme delicacy, the Cornea is actually thicker than the Sclerotic (being about $\frac{1}{25}$th of an inch thick); and, according to Professor Valk, consists of five layers:—

1. Conjunctival epithelium.
2. Bowman's elastic lamina.
3. Cornea proper.
4. Membrane of Descemet or Demours.
5. Endothelium.

The central layer—the Cornea proper—is a thick, fibrous structure possessing many layers of connective tissue, the fibres of which are continuous with those of the Sclerotic, forming the foundation; it is horn-like in substance and non-sensitive, and is perforated by numerous lymph spaces for nourishment of the Cornea.

Bowman's membrane is a sensitive layer of elastic tissue, and protects the Cornea proper anteriorly; whilst Descemet's membrane besides performing a similar service to its posterior surface, is remarkable for its extreme elasticity, the value of which, as suggested by Dr. Jacob, appears to be "to preserve the requisite permanent correct curvature of the flaccid Cornea proper."

The Epithelium and Endothelium are respectively the most external and internal protective coverings. Lining the inner surface of the Sclerotic is the second coat of the eye, the Choroid. This is dark brown in colour, and contains nearly all the blood vessels of the eye, and is covered on its inner surface by a layer of black pigment cells, which serve to absorb all superfluous light; in this way preventing reflection in the eye, which would otherwise seriously interfere with the vision. It

may be briefly stated to have two layers, one vascular, the other pigmentary; and is separated from the Retina by an almost structureless membrane, named after Brück. As the Choroid approaches the front of the eyeball, its structure undergoes an alteration, and it divides into two layers; one of which develops into a series of folds (about 70 in number), constituting the Ciliary processes, which form the internal portion of the Ciliary body, lying against the Hyaloid covering of the Vitreous Humour. The external part consists of the Ciliary muscle, situated between the processes and Sclerotic coat (at the Sclero-corneal junction, behind the base of the Iris). This muscle consists of two sets of fibres, radiating and circular, the latter being internal to the radiating ones; and is sometimes known as the "ring muscle" of Müller. The Ciliary muscle is connected to the Lens capsule by the suspensory ligaments or Zonule of Zinn (which are a continuation of the anterior portion of the Hyaloid membrane); so that by contraction it influences the tension exerted by the ligaments on the Crystalline Lens. It is thus the chief agent of Accommodation, and is generally spoken of as the "muscle of accommodation"; whose function is to adapt the eye for seeing objects distinctly at various distances.

The other extension of the Choroid inwards, beyond the Ciliary processes, forms a muscular and perforated diaphragm, the Iris, which extends across the globe of the eye; being firmly attached at the sclero-corneal junction, and dividing the front cavity into two chambers, the anterior and posterior. The anterior chamber is the space between the Cornea in front and the Iris and lens behind. The posterior chamber is bounded by the back surface of the Iris in front and by the Ciliary processes, suspensory ligament and periphery of Lens capsule behind. These two chambers are filled by the Aqueous Humour, and communicate through the opening of the Iris. At the base of the Iris is the pectinate ligament, connecting it with the periphery of the Cornea; which

Section from the Human Eye (photographed by Mr. W. Green) through the Ciliary region, showing Ciliary processes and muscle, together with the ora serrata.

contains a number of minute openings called the spaces of Fontana, through which the Aqueous Humour is said to filter into the circular Canal of Schlemm, extending around the Cornea at its union with the Sclerotic, from whence the secretion passes into the anterior Ciliary veins. This angle where the Iris and Ciliary processes unite with the Cornea, is known as the Iritic (filtration) angle; and the importance of the relation of its parts may be gathered from the fact that recent authorities consider the stoppage of the little canals which it contains, to be a prominent cause of *Glaucoma*—a disease due to increased tension of the intra-ocular fluids, owing to their outlet being obstructed.

The Iris, which structure is seen through the Cornea, varies in colour in different individuals; the difference observable in the colour being dependent upon the amount of pigment which covers the posterior surface of the Iris. The eyes of newly-born infants are nearly always light blue, and they do not assume their permanent colour until about the sixth week of life. The function of the Iris is to regulate the quantity of light which is to enter the interior of the eye. In its centre is a round aperture, which appears as if it were a black spot; this is known as the Pupil. The reason of its appearing like a black spot is because there are no rays of light passing from the eyes of the observer to illuminate it. If a light is placed in such a way as to illuminate the Pupil, the rays return to the source of the illumination. If the observer attempts to intercept these return rays, and thus obtain a view of the interior of the eye, as soon as he places his own eye in the path of these return rays, he immediately shuts off the source of light, and there are no rays to return, consequently, the pupil appears dark.

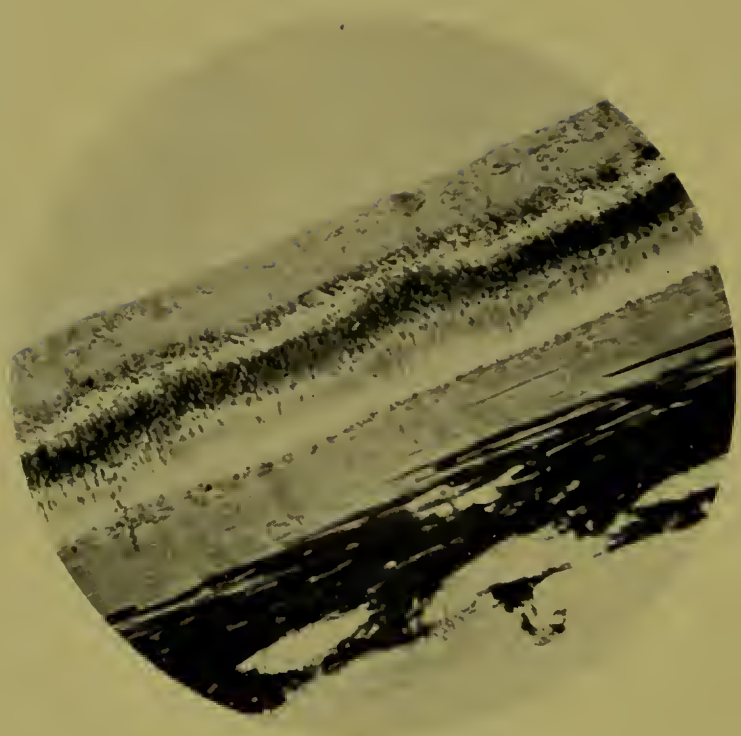
The muscular arrangement of the Iris consists of radiating fibres from the periphery to the centre, and circular fibres forming a sphincter muscle on the aperture of the Pupil; the former by contracting enlarges the Pupil, and the latter makes

it smaller, also by contraction. This muscular system is quite involuntary, therefore we cannot alter the size of the Pupil by any effort of will. The aperture of the Pupil is regulated by the intensity of the light to which the eye is exposed; it contracts also with accommodative and convergent efforts.

The third layer is the Retina, an expansion of the Optic Nerve, which enters the back of the eye, a little to the nasal side, through the Sclerotic and Choroid. The Retina lies on the anterior face of the Choroid, and extends from the point of entrance of the Optic Nerve as far forward as the Ciliary processes, where it forms a jagged border called the "Ora Serrata."

The Retina is the most important structure of all, for on it are impressed all images of external objects; these images being conveyed to the brain by the Optic Nerve, which springs from the base of the brain, and enters through the back of the Sclerotic and Choroid, and then spreads out, forming itself into that thin, delicate network, the Retina. This coat is perfectly transparent and colourless in life, but after death it becomes of a greyish hue. It is made up entirely of rods, cones, and other structures, which are absolutely essential to enable the light to give that necessary stimulus which, when conveyed to the brain by the Optic Nerve, is converted into visual sensations. It is the absence of the cones which makes the entrance of the Optic Nerve insensitive to light; and the abundance of them that renders the "yellow spot" so exceedingly sensitive—this is the portion of the Retina where we have the most acute vision. (These two parts of the Retina will be referred to again later on). Although the Retina is actually only about the one hundred and twentieth part of an inch thick, it is seen microscopically to be composed of no less than ten distinct layers; these (according to Gray), given from within outwards, are:—

1. Membrana limitans interna; a delicate membrane in contact with the Hyaloid of the Vitreous Humour.



Transverse section through the Retina and Choroid (highly magnified from a photograph by Mr. W. Green), showing the various layers of the Retina, and also the pigmented layer of the Choroid.

2. Layer of nerve fibres; these are the continuation of the fibres of the Optic Nerve, showing that this nerve passes through all the other retinal layers except the innermost one.

3. Vesicular layer; consisting of a single layer of ganglion cells, except at the Macula, where there are several layers.

4. Inner molecular or granular layer.

5. Inner nuclear layer, consisting of nuclear bodies.

6. Outer molecular layer; this is thinner than the inner molecular, and consists of a dense network of minute fibres presenting a granular appearance.

7. Outer nuclear layer, having several strata of nuclear bodies.

8. Membrana limitans externa. (The supporting fibres of Müller pass from within outwards, connecting the layers of the Retina from 1 to 8).

9. Jacob's membrane; consisting of rods and cones, the former being the more numerous, except at the Macula region, where the cones are more abundant; and at the Fovea Centralis the rods are entirely absent. This is the so-called "perception layer" of the Retina.

10. Pigmentary layer.

From a physiological point of view, Donders reduced the retinal layers to three, viz.:—

1. The fibrous layer of the Optic Nerve.
2. The layer of rods and cones; the percipient layer.
3. The connective tissues between these two extremes.

It is generally conceded that the external layer of rods and cones (Jacob's membrane), is the percipient layer of the Retina; and this is supported by Purkinje's experiment, which is, to move to and fro, close to one's own eye a lighted candle in a room otherwise darkened; when, by looking steadily

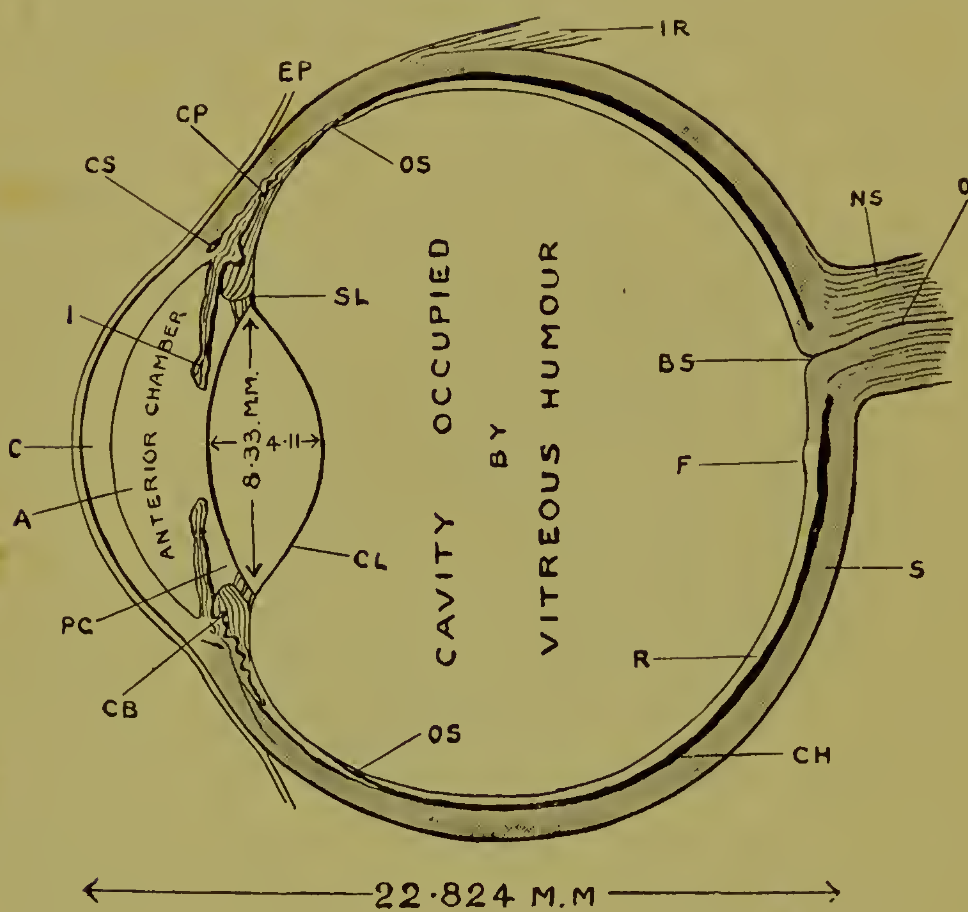


FIG. I.

A Aqueous Humour.
BS Blind Spot.
C Cornea.
CB Ciliary Body.
CH Choroid.
CL Crystalline Lens.
CP Ciliary Processes.
CS Canal of Schlemm.
EP Epithelial Layer.
F Fovea.
I Iris.
IR Internal Rectus.
SL Suspensory Ligament.
NS Nerve Sheath.
ON Optic Nerve.
OS Ora Serrata.
PC Posterior Chamber.
R Retina.
S Sclerotic.

forward in the darkness, one can see the shadows of the retinal vessels on a reddish ground floating before the eye. This affords clear proof that the light-perceiving elements of the Retina are the external layers; as the blood vessels causing

these shadows must be situated in front of the layer perceiving them.

The humours, from before backward, are :—

1. Aqueous.
2. Crystalline Lens.
3. Vitreous.

The Aqueous Humour is a transparent liquid, consisting almost entirely of water, with a small quantity of saline material in solution. This fluid fills the anterior and posterior chambers of the eyeball, which are divided by the Iris. By a fortunate provision of Nature, the Aqueous Humour, in the event of leakage from accident or from such an operation as the removal of Cataract necessitates, can be reproduced in about eight hours.

The Crystalline Lens is situated directly behind the Iris. It is an elastic body, and resembles a small and very strong magnifying glass; double convex in shape, but less convex in the front than at the back; the anterior radius being 10 m/m, and its posterior radius 6 m/m. It is transparent as crystal, as its name implies, and measures about one-third of an inch, or 8·33 millimetres in diameter, and one-sixth of an inch, or 4·11 millimetres antero-posteriorly. The Crystalline Lens consists of concentric layers, the outer ones of which are soft and pliable, whilst the nuclear portion is harder and of firmer substance. The density of the lens varies from its nucleus to the periphery, being gradually less dense towards the outer layers; thus neutralizing to a certain extent the effect of spherical aberration, and bestowing upon the eye the power of a wide field of vision, without changing the position of the point of sight; in which the marginal rays are as distinct and clear as the central ones. As a person ages, the Crystalline Lens becomes of uniform density, so that spherical aberration is more noticeable than in youth, which accounts for the contraction of the Iris in advanced age, to shut off the

peripheral rays, and so lessen the aberration. The partial or total opacity of the Crystalline Lens constitutes the disease known as Cataract. The operation for Cataract consists in extracting from the eye this lens when it has become opaque. It is erroneous to imagine that Cataract is merely a skin over the eye, and that this only is required to be removed in order to cure the disease. The Crystalline Lens itself must be taken out or absorbed. The resulting refractive condition of the eye is known as Aphakia (see Chap. XII.).

The Vitreous is the third and last of the humours, which, together with the Cornea, form the refractive media or dioptric apparatus of the eye, as they are sometimes called. In appearance and substance it is a fine, transparent jelly, and occupies the larger posterior cavity of the globe, between the back of the Crystalline Lens and the front of the Retina. It is maintained in shape by the outer wall of the eye, without which it would collapse into a formless mass; and it, in turn, also keeps the coats of the eye in contact. The Vitreous Humour is enclosed in a thin, delicate, transparent covering termed the "hyaloid membrane"; which serves to prevent the Vitreous Humour from adhering to the Crystalline Lens, and thus facilitates the action of the accommodation. The lens is not placed loosely in the eyeball, but is situated in the anterior depression of the Vitreous body (Hyaloid fossa), and is enclosed in a transparent and elastic capsule; being held in position by the suspensory ligaments—anterior and posterior, arising at the Ora Serrata from the Hyaloid membrane—which encircle the periphery of the lens capsule and exert a restraining influence upon the Crystalline Lens, keeping it at its least degree of curvature. The small triangular portion formed by the anterior and posterior ligaments and the edge of the Crystalline Lens is not a solid structure, but is perforated by minute circular passages which collectively are known as the Canal of Petit. This suspensory ligament not only helps to retain the lens in position, but is capable of altering its shape.

This is brought about by the action of the muscle of accommodation (Ciliary muscle) on this ligament; the muscle being attached to it, both in a state of contraction and when at rest. The suspensory ligament in its normal position keeps the lens somewhat less convex, by the pressure exerted on it. The alteration in the form of the lens is due to the action of the Ciliary muscle, which draws forward the Choroid, and by so

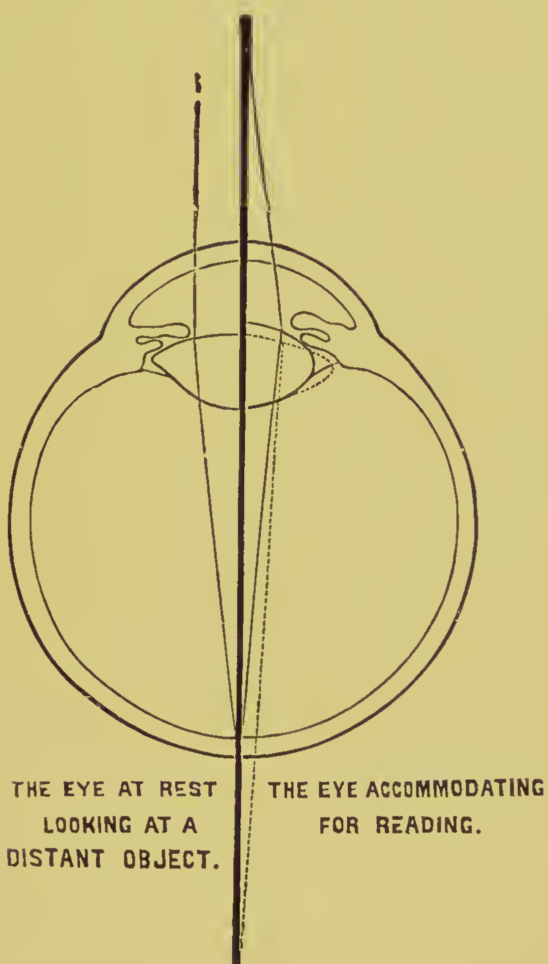


Fig. II.

doing slackens the tension of the suspensory ligament which arises from it. The anterior surface of the lens is kept flattened by the action of this ligament. The Ciliary muscle, during accommodation, by diminishing its tension, diminishes to a proportionate degree the flattening of which it is the cause. On cessation of the action of the Ciliary muscle, the

lens returns to its former shape, by virtue of the elasticity of the suspensory ligament.

The theory of accommodation just described is such as advanced by Helmholtz, and the one perhaps most generally understood. However, another theory, propounded by Tscherning, maintains that, since the lens nucleus is harder and of shorter radius than the outer layers, traction at the periphery causes the lens to assume an increased curvature at the centre, whilst the periphery is flattened; the lens being then somewhat conical in formation.

Although the authorities are at variance as to the actual mechanism of accommodation, there is now no doubt that the change which does take place in the lens is an increased convexity of its anterior surface. This can be proved by the following experiment, demonstrating Sanson's images (also sometimes called after Purkinje):—

If a lighted candle is held slightly to one side of a person's eye, an observer looking at the eye from a corresponding position on the other side, sees three images of the flame. The first, formed by the anterior surface of the Cornea, is bright, small and erect; the second, also upright, is larger and less clear, being formed at the anterior surface of the lens; the third image is indistinct, small and inverted, formed at the posterior surface of the lens. If now the eye under observation be made to accommodate by viewing a close object, the second image will be noticed to become smaller and clearer, and to approach the first. If the eye is now again adjusted for distant vision, this image assumes its original position and appearance. The first and third images have not changed during this experiment; thus proving that the only alteration in the lens during accommodation is, that its anterior surface increases in curvature, and bulges forward, approaching the Cornea.

The whole surface of the back of the eye is not, if you remember, equally sensitive; the Papilla or Optic Disc (*i.e.*, where the Optic Nerve enters the back of the eye, and begins

to spread out into the Retina) is completely insensitive to light, and has consequently been called the "blind spot." Light falling upon it produces no effect. The reader may locate his own blind spot, by fixing his left eye upon the small spot in the illustration below, and closing his right eye. By means of

Fig. III.

our indirect vision the larger square will also be seen, although the attention is only given to the spot. By moving this page to and fro from the face, a position will be found in which the square suddenly disappears from view; this is because, in this position, rays from the square fall exactly upon the "blind spot" of the left eye, and consequently produce no effect. On moving the paper again slightly, it will again merge in view. The reason why the blind spot causes us no inconvenience is, that rays cannot fall on the blind spot of each eye simultaneously, as they are both situated towards the nasal part of the Retina. If rays from an object fall upon the blind spot of the right eye, they fall upon the sensitive area of the Retina of the left, and *vice versâ*.

About one-tenth of an inch to the temporal side of the Optic Disc is the yellow spot (Macula Lutea), which is the most sensitive portion of the Retina. The very centre of the Macula region is termed the "fovea centralis," and is the thinnest part of the entire Retina, which, however, becomes thicker immediately beyond the Macula area, and lessens in thickness gradually as it extends forwards to its termination at the Ciliary region. Under normal or natural conditions of the eye, all images of external objects are focussed on the Fovea Centralis, if they are to be seen perfectly. The Retina is most sensitive to light in the centre, and gradually becomes less so as it approaches its periphery, towards the ora serrata.

The eyeballs are embedded to a large extent in the fatty

cushion which lines the inner surface of the orbits, although they are not actually in contact with it, being enclosed almost completely (from the posterior of the globe, where the Optic Nerve makes its entrance through the layers, to just behind the corneal margin) by the capsule of Tenon, a thin membraneous sac which permits free movement of the globe. This membrane is pierced by the extra-ocular muscles (those outside the eye), near their insertion in the Sclerotic. These muscles all have their origin (with the exception of the Inferior Oblique) at the inner extremity of the orbit rising from a band of fibrous tissue (sometimes called the circle of Zinn[1]) which surrounds the bony opening, the Optic Foramen, through which the Optic Nerve comes from the brain; and their insertion is in the Sclerotic.

The muscles governing the movements of the eye are six in all; four straight or recti (so called because they run a straight course from the back of the orbit), and two oblique. Their nomenclature, origin, and insertion in the Sclerotic, are as follows:—

The *Superior Rectus*, weakest and longest of the four recti muscles, arises from the upper and outer margin of the Optic Foramen, which is the opening in the posterior of the orbit through which the Optic Nerve sheath passes. Travelling upwards, forwards, and slightly outwards from its origin, it is inserted almost 8 m/m above and behind the corneal border.

The *Inferior* and *Internal recti* arise by a common tendon which is attached round the circumference of the Optic Foramen, at its lower and inner part. The Inferior proceeds outwards and downwards, and is inserted just over 6 m/m behind the Cornea; the Internal (broadest and strongest muscle) travels almost straight forward, and has its insertion about 5 m/m back of the corneal margin.

The *External Rectus* (second strongest of the straight

[1] This should not be confounded with the Zonule of Zinn, which is a collection of fibres forming a connection between the Ciliary muscle and the Lens capsule.

muscles) has two heads, both arising from the immediate vicinity of the Optic Foramen; and proceeding forwards and outwards, its scleral insertion is 7 m/m from the edge of the Cornea.

The *Superior Oblique* (longest of all the muscles) arises just above the inner margin of the Optic Foramen; and passing forward to the inner and upper angle of the orbit, terminates in a rounded tendon which passes through a pulley, and is deflected backwards, outwards and downwards beneath the Superior Rectus, to the outer part of the globe of the eye, where it is inserted into the Sclerotic midway between the Cornea and entrance of the Optic Nerve, the insertion of the muscle lying between the Superior and External recti.

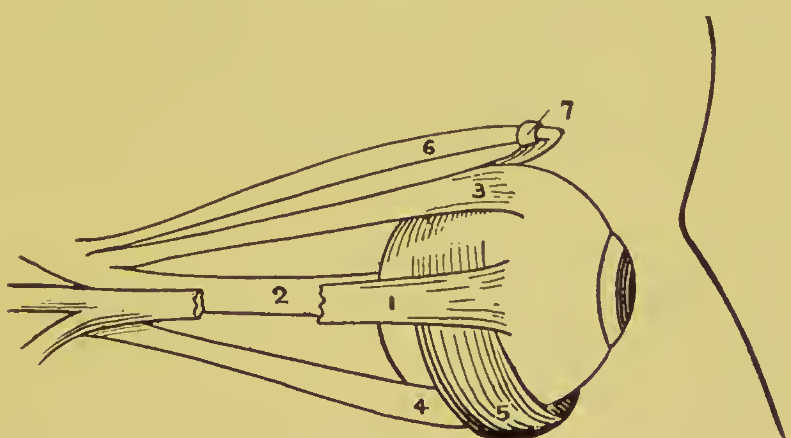


FIG. IV.

1. External Rectus.
2. Internal Rectus.
3. Superior Rectus.
4. Inferior Rectus.
5. Inferior Oblique.
6. Superior Oblique.
7. Pulley through which No. 6 passes.

The *Inferior Oblique* (shortest of all the muscles) is a thin muscle placed near the anterior margin of the orbit, arising from a depression in the orbital plate of the superior maxillary bone; thus it is the only one of the six motor muscles that has not its origin around the Optic Foramen. Passing outwards, backwards and upwards, beneath the Inferior Rectus, and between the eyeball and External Rectus, it is inserted into the outer part of the Sclerotic between the Superior and External recti, near the insertion of the Superior Oblique.

The Internal and External recti muscles turn the eye in the directions which their names indicate; *i.e.*, inwards and outwards respectively. The Superior and Inferior recti, however, do not pull the globe *directly* upwards and downwards; these movements being accompanied by an inward deviation which is counteracted by the Obliques. The Superior Oblique turns the eye down and out; and in association with the Inferior Rectus, allows the eye to look directly downward. The Inferior Oblique rotates the eye up and out; and, in conjunction with the Superior Rectus, turns the eye directly upward.

The *Oblique* muscles *alone*, turn the eye on its anterior-posterior axis; and, associated with the recti muscles, turn the eye in all directions.

The perverted action of either the oblique or recti muscles constitutes the defect known as squint (Strabismus).

Below will be found a table giving the names of the several muscles brought into play when looking in the various directions:—

Outwards—The External Rectus.
Inwards—The Internal Rectus.
Upwards—The Superior Rectus and Inferior Oblique.
Downwards—The Inferior Rectus and Superior Oblique.
Out and up—The External and Superior Recti and Inferior Oblique.
Out and down—The External and Inferior Recti and Superior Oblique.
In and up—The Internal and Superior Recti and Inferior Oblique.
In and down—The Internal and Inferior Recti and Superior Oblique.

Previous to closing this chapter, it would be well for the student to possess himself of a slight knowledge of the lachrymal apparatus of the eye. As one of the essentials of life is cleanliness, the eye has a complete equipage for this purpose, which is called the lachrymal or tear apparatus. This

consists of the gland from whence the tears come, and the ducts or canals leading to the cavities of the nose, by which the tears, after having been washed over the surface of the Cornea, make their exit. On the temporal and upper side of the orbit (the resting place of the eyeball), is a depression in which lies the Lachrymal Gland. This is oval, and not unlike an almond in shape and size. Its function is to secrete tears. Its inferior surface rests directly on the eyeball, and there are several small ducts (seven to ten in number), leading from this to the inner surface of the lids, through which the secretion flows over the anterior surface of the eyeball, and thus keeps it moist and free

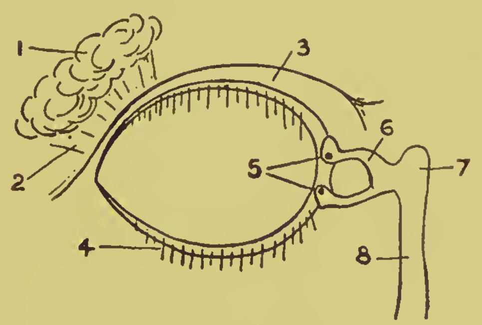


Fig V.

1. Lachrymal Gland.
2. Ducts.
3. Upper Eyelid.
4. Lower Eyelid.
5. Lachrymal Points.
6. Lachrymal Canal.
7. Lachrymal Sac.
8. Nasal Duct.

from foreign bodies, such as dust. This discharge is brought about by the movements of the lids, and is the reason one always blinks if there is any foreign matter in the eye, so as to encourage the flow of tears, which wash anything that may be there into the nasal duct. The fluid of the Lachrymal Glands flows inwards and downwards, and is then absorbed through two little apertures, one in each lid. The one on the lower lid is distinctly visible on drawing it down somewhat with the fingers. It then passes through the Lachrymal Canal on its way to the nasal duct, and finally into the nose. The lids are lined by the mucous membrane of the eye, or Conjunctiva. This membrane is transparent, and richly supplied with blood-vessels. It begins at the edges of the eyelids, covering their

posterior surfaces to about the equator of the eyeball, to which it is loosely attached. Here it folds forward over the Cornea, in this way covering the front of the eye. Thus the Conjunctiva forms a sac, of which the palpebral fissure (*i.e.*, the opening of the lids) is the outlet; so that it is the lodging place of foreign bodies which may enter the eye. These, if they do not become embedded in the Conjunctiva tissues, eventually travel, owing to the direction of the flow of tears, to the inner canthus, where they can be readily removed.

CHAPTER II.

REFRACTION, LENSES AND REFLECTION.

BEFORE going into details as to the perfect eye, and studying the various ways in which an eye may differ from normal conditions, it will be necessary to give a few pages to the elementary laws of refraction and to lenses and their properties, and also to the laws of reflection.

To begin with—as far as we are concerned in Visual Optics—light may be considered as a force which emanates from luminous bodies and travels in straight lines at a great speed (about 187,000 miles per second), through an element termed luminiferous ether, which pervades all space; and, through the intervention of the Retina, the Optic Nerve and the Brain, produces in us the phenomena of sight. The smallest conceivable line of light is called a *ray;* and when these rays travel side by side in the same direction (or parallel), they are called a *beam.* When rays of light proceed from a point, and gradually separate as they travel; or when rays are approaching a common point, they are termed a *pencil* of light. Thus we have, in the first case, a *diverging pencil*, and in the latter, a *converging pencil.* In nature, all rays of light are divergent; but for practical purposes, those coming from a distance of twenty feet (six metres) or more, may be considered as being parallel. Rays from near objects (that is, from those situated at less than twenty feet) are looked upon as divergent; and the closer the object is brought to the eye the more divergent are the rays emanating from it.

In the following pages, therefore, rays of light will be spoken of as parallel when coming from a distance of twenty feet or more; and as divergent when coming from near objects. We are considering the rays, of course, as they enter the eye.

Rays of light, in passing from one transparent medium to another of different density, are said to be "refracted," when they deviate from the direction in which they were proceeding, before entering the new medium; and this deviation is called Refraction.

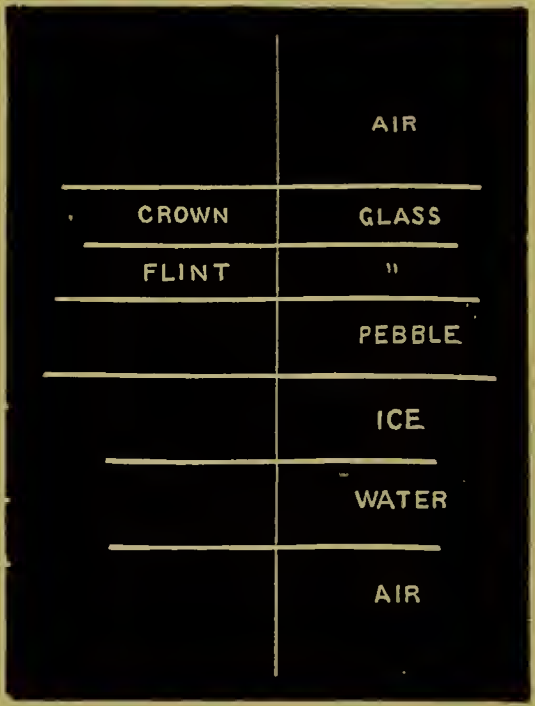


Fig. VI.

When rays of light pass from a rare into a denser medium, they are deviated or bent towards a normal or perpendicular line drawn to the surface of the medium at the point of entrance. In passing from a denser to a rarer medium, they are refracted away from a perpendicular or normal drawn to the surface of the medium at the point of emergence.

Fig. VI. shows that a ray of light will continue its straight course, unaltered, through any number of different transparent media, no matter what their densities; so long as it forms right

angles with the surface or surfaces separating the different media. Such a ray is called the normal or perpendicular.

In Fig. VII. AB, and ST, are the parallel faces of a plate of glass, or other medium denser than air. If DC represents the path of a ray incident at C, CE will represent its path within the glass, bent inwards towards the normal. At E the ray emerges from the glass, in the direction EF, whose outward refraction or bending is equal to the inward bending experienced at C. Hence the emergent ray is in this case parallel to the incident ray.

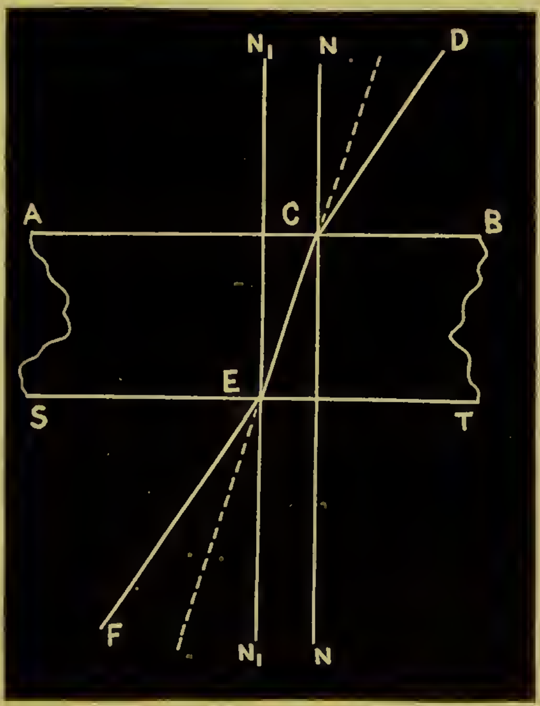


Fig. VII.

In the foregoing figures, the surfaces of the refracting media are parallel; but in the case of a prism, the surfaces are not parallel, but inclined one to the other, and consequently a ray cannot possibly be perpendicular to both surfaces at once. Rays falling on a prism are refracted, and the deviation is always in the direction of the base, and since similar rays of light falling upon a prism are all equally bent or refracted,

those which are parallel to each other before entering, remain parallel after passing through the prism.

If DE (Fig. VIII.) is a ray falling on a prism ABC at E, it is bent or refracted towards the base of the prism (towards the perpendicular), assuming the direction EF; on emergence it is once more refracted at F; this time going from the perpendicular. An observer situated at G, would receive the ray as if it came from H.

From the following diagram we may deduce two rules, which we should remember, as follows:—

1. Rays of light falling on a lens (except when falling at right angles to both its surfaces, when of course it would undergo no refraction) are always refracted or bent towards the thicker part.

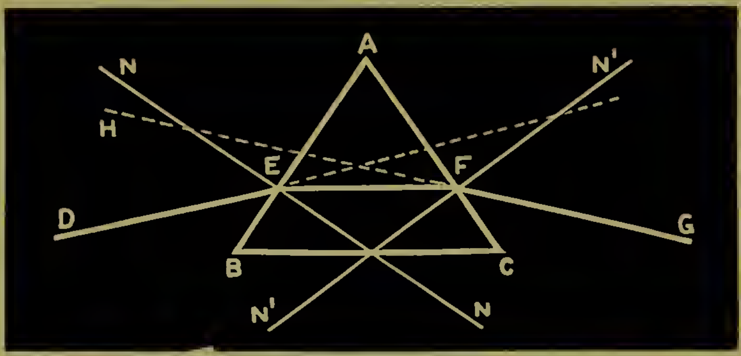


FIG. VIII.

2. An object seen through a prism appears to be displaced or moved in the direction of its apex.

The amount of deviation undergone by rays of light falling on a refracting surface depends to a great extent upon the degree of obliquity at which they enter the medium; as the more obliquely rays fall on a refracting substance, the greater is the amount of refraction which they undergo; and the effect produced depends also upon the difference in refraction of the two media; that is, upon their refractive indices. "Index of refraction" is a number used to denote the refractive power of any transparent substance, when compared with that of air, which is taken as the standard and is called 1; the index of

refraction of water is 1·33 and of crown glass, 1·5 (glass used for spectacle lenses is 1·52). Thus the index of refraction of any substance is its refractive power compared with that of air, numerically expressed. To trace the direction taken by a ray of light travelling from air to any other medium having a different index of refraction, it is only necessary to know the angle of incidence at which the ray enters the medium, and the refractive index. Given these particulars, let AB be the surface separating the two media (say air and water), and CD the perpendicular to same.

Draw the incident ray EF, at the given inclination; and with centre F and radius FE, describe a circle. Draw a perpendicular from E to AB at G and divide GF into four equal parts;

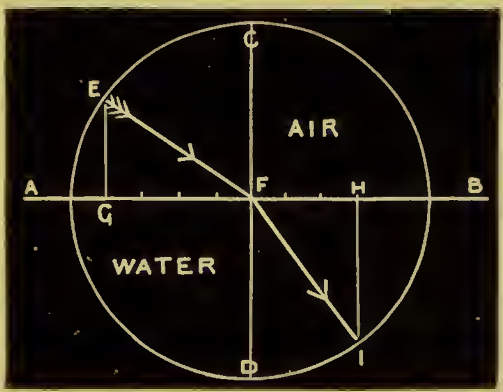


FIG. IX.

then mark off a distance FH, equal to three of these divisions (the refractive index of water being 1·33 or $\mu\frac{4}{3}$). Now draw a perpendicular from H, extending same until it meets the circumference of the circle at I; connect I and F and you have the direction of the refracted ray. (See Fig. IX.)

If the second medium had been glass, with an index of refraction of 1·5 (or $\mu\frac{3}{2}$) you would divide FG into three equal parts and FH would equal two of these. To reverse the process, that is, to ascertain the direction of a ray proceeding from water to air ($\mu\frac{3}{4}$) the same method may be followed. Fig. X. shows AB as the surface separating the media, CD the perpendicular, EF the original ray and the circle having a radius FE. Drawing

a perpendicular from E to AB at G, we divide GF into three equal parts and mark off a distance equalling four of these from F to H; a perpendicular from H to I is now drawn, and FI is the direction of the refracted ray. Not all the rays emanating from the

FIG. X.

luminous point E emerge from the water; some run along the surface and others suffer total reflection and are sent backwards from the surface separating the media; this depends upon the obliquity at which the rays strike it. The critical angle is the angle at which an incident ray, travelling from a denser to a rarer medium, cannot emerge; and beyond this angle, under

FIG. XI.

similar conditions, a ray suffers total reflection. The critical angle decreases as the index of refraction increases. This angle may be found as follows (see Fig. XI.) Let AB be the surface separating the water from the air ($\mu \frac{4}{3}$), CD the perpendicular.

With centre E and any radius, describe a circle cutting the line of separation at B; divide BE into four equal parts and mark off EF equal to three of these divisions. From F draw a perpendicular to the surface, cutting the circle at G, join EG, when GED will be the critical angle. Rays forming a greater angle than this will be reflected back into the water; thus suffering total reflection. Total reflection due to refraction, is made use of in prism-binocular and other optical instruments. Reference to Fig. XII. will show the behaviour of parallel light incident upon a right angled prism in such a manner as to be influenced by the critical angle. Parallel rays falling upon the prism at right angles to the surface BC, enter without undergoing refraction, and therefore meet the opposite surface BA at an angle of 45°, which is greater than the critical angle (this being 41° 45′ for

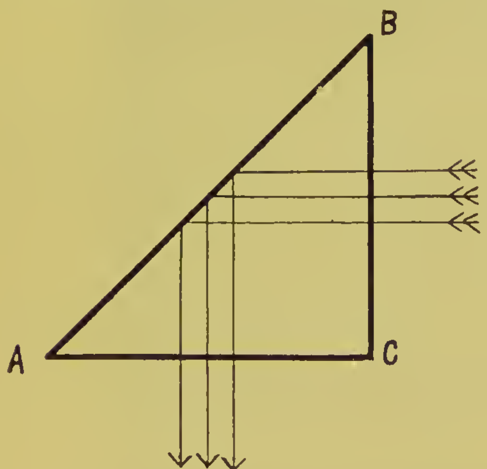


Fig. XII.

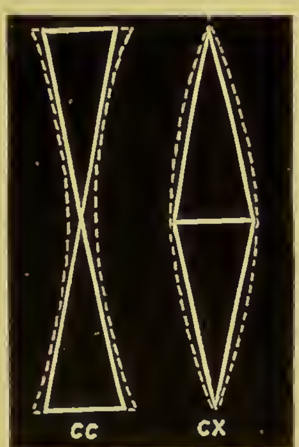


Fig. XIII.

crown glass, having an index of refraction of 1·5), and therefore suffer total reflection at this surface; leaving the prism at right angles to surface AC, without deviation, and travelling at angle of 90° from its original incidence.

Spherical lenses may be considered as being composed of an innumerable number of prisms, convex with their bases, and concave lenses with their apices together arranged towards a central point. According to the first rule given on page 22, it will be readily seen that convex lenses cause rays of light, on passing through them, to be bent inwards or converged; and

that concave lenses cause them to be bent outwards or made divergent. CX represents a convex lens, and CC a concave in Fig. XIII. (For simplicity of drawing the lenses are shown here as being composed of only two prisms).

A ray of light that passes through the centre of a lens

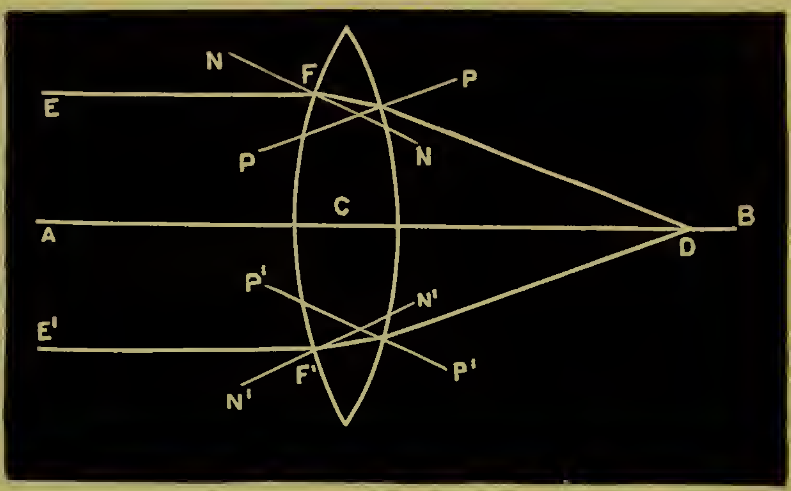


Fig. XIV.

(optical centre), at right angles to its surfaces, is called the "principal axis," and a ray of light that coincides with this principal axis undergoes no refraction.

In Fig. XIV. AB indicates the principal axis of parallel rays falling *directly* on the lens, *i.e.*, at right angles to its central surface. This axis, like the ray which it represents, passes through the optical centre C, without deviation.

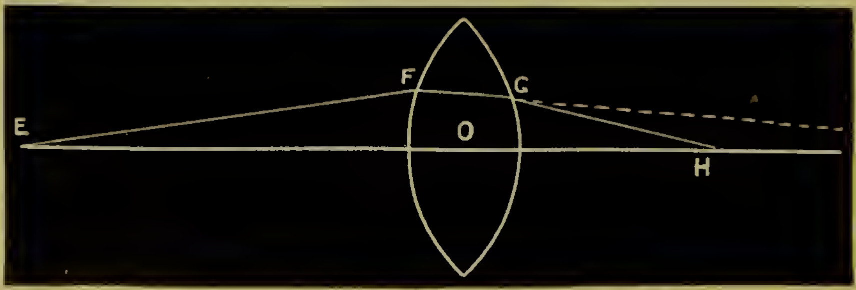


Fig. XV.

The rays E and E[1] strike the lens obliquely at F and F[1], and are bent towards the perpendiculars NN and N[1]N[1] on entering; and on emergence, away from the perpendiculars PP and P[1]P[1],

and meet the principal axis at D, the principal focus. This figure shows clearly that convex lenses render parallel rays convergent. The prefix + (plus) is used to denote convex lenses.

In the case of a small divergent pencil from E (Fig. XV.), in the principal axis, falling directly on the lens, a ray EF is refracted at the first surface, in the direction, say FG, and, at the second surface, in the direction GH; E and H are called "conjugate foci," and, if EO = OH, they are known as the secondary foci of the lens.

In Fig. XVI. the ray AB falls upon the lens, at right angles; and is therefore not refracted. The rays E and E^1 strike the

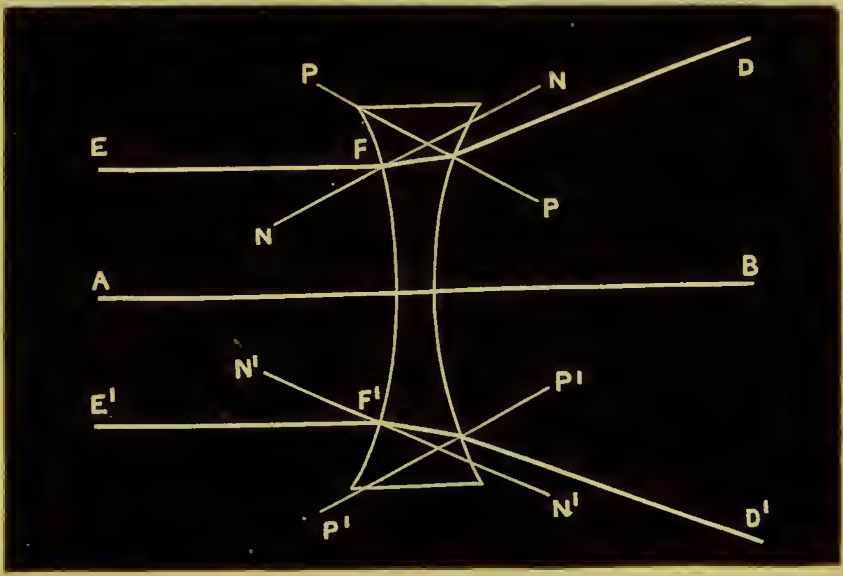


FIG. XVI.

lens obliquely at F and F^1, and are refracted towards the perpendiculars NN and N^1N^1. On emergence they are bent away from the perpendiculars PP and P^1P^1, in the directions D and D^1. It is seen, then, that concave lenses render parallel rays traversing them divergent. The algebraical sign − (minus) signifies concave lenses.

All rays that do not pass through the principal axis of a lens are refracted; so those that pass through the optical centre, but not through the principal axis, do suffer a slight

displacement; but in thin lenses it is so inconsiderable that they are assumed to pass unrefracted. Such rays are called secondary axes, and are innumerable; whereas there is only one principal axis. The optical centre of a spherical lens is that point at which the secondary axes cross the principal axis. Parallel rays passing through a concave lens are rendered divergent; consequently the focus will be a virtual, negative one, situated on the same side of the lens as the object. A "virtual" focus is one formed by the prolongation backward of rays to a point, and is really non-existent. The focus of a convex lens, however, is formed by the actual meeting of the rays in a point, and is therefore termed "real." If the divergent rays in Fig. XVIII. be prolonged backward, they will meet at v, which is the principal focus of the concave lens.

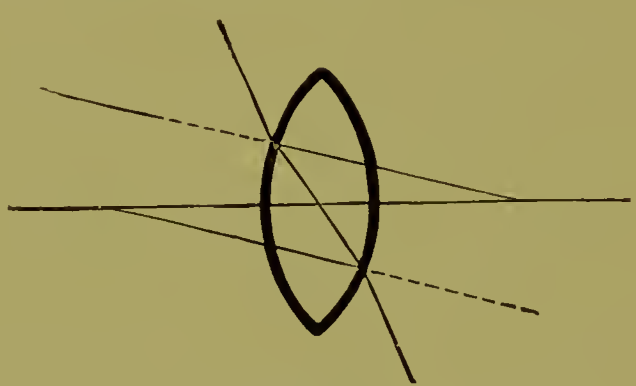


Fig. XVII.
Showing secondary axis.

We have seen that convex lenses converge the rays of light, so that they meet at a definite point on the opposite side of the lens; the distance of this point from the optical centre is called the "focal length," and the point at which the rays meet is called the focus—positive when formed by a convex lens, and negative when produced by a concave one.

The focal length of a lens varies *inversely* with the power of the lens, *i.e.*, as the strength increases, the focal length becomes less; and the *position* of the object regulates the location and formation of the image. Thus, if an object is

placed at infinity, the image formed by the convex lens will be real, inverted, diminished, and situated at what is known as the *posterior principal focus.* As the object is brought towards the lens, approaching the *anterior secondary focus*,[1] the inverted image will recede towards the *posterior secondary focus*, increasing slightly in size, but still smaller than the object.

If the object is at the *anterior secondary focus*, the image will be real, inverted, the same size as the object, and situated at a corresponding distance on the other side of the lens, at the *posterior secondary focus.* As the object approaches the *principal focus*, the image recedes towards infinity, gradually increasing in size until the object reaches the principal focus, when the rays, after refraction by the lens, being parallel, there is no image formed at all.

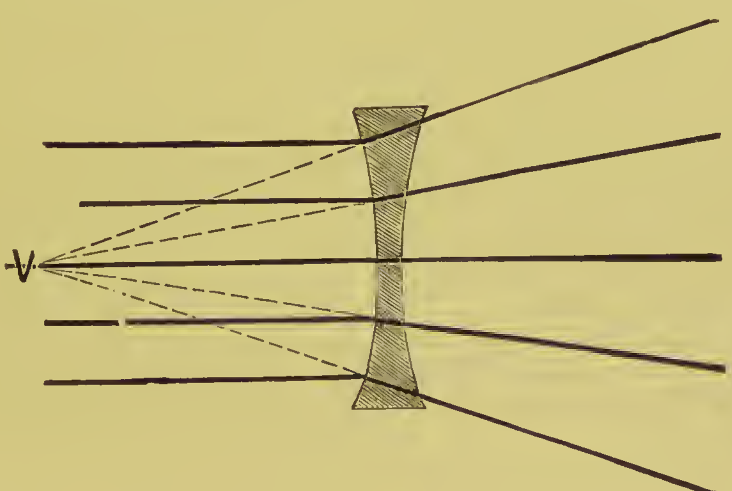


FIG. XVIII.

If the object is placed between the principal focus and the lens, the image will be virtual, erect, enlarged, and situated on the same side of the lens as the object, but further back. As the object approaches the lens, so does the virtual image, until the object touches the lens, when it and the image are of one size and situated at the same place. The image formed by a concave lens is always virtual, erect, smaller than the object,

[1] According to some writers the "secondary foci" are termed "symmetrical points," and planes raised on the axis at these points are called "symmetrical planes."

and situated in front of the lens, but never further back than the principal focus. When the object touches the lens, the image is of the same size and situated at the same place.

It will be seen from the above that convex lenses form a real image, when the object is beyond the principal focus, which image is smaller than the object until the object reaches the secondary focus, when it is the same size. Within the secondary focus the image is larger than the object until the principal focus is reached, when there is no image formed. When the object is nearer than the principal focus, a virtual, enlarged image is formed, gradually decreasing in size as the object approaches the lens. Thus the image formed by a convex lens is either real or virtual, according to the distance of the object. *Real images* are always *inverted*, and *virtual ones* are always *upright*. This is very clearly shown in the accompanying diagram (Fig. XIX). The capital letters on the

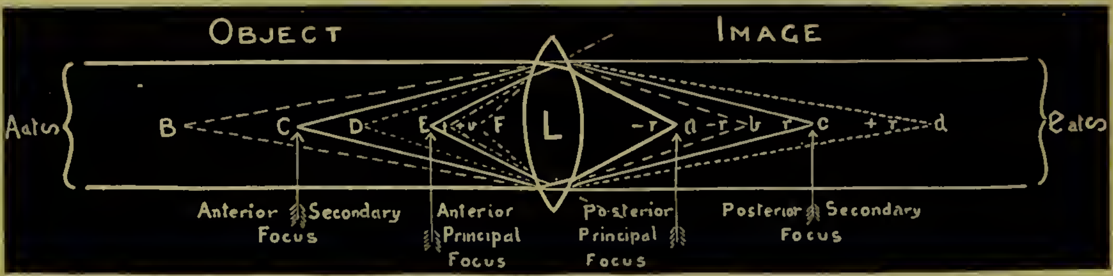


FIG. XIX.

∞ = Infinity. r = Real and Inverted. v = Virtual and Erect.
\+ = Enlarged. – = Diminished.

left indicate the position of the object, and the corresponding small letters show the positions of the respective images. A careful study of this diagram will be found of great assistance in understanding the formation of images by a convex lens. It will be noticed that the object and image bear a reciprocal relation to each other, and they are called *Conjugate Foci.* That is to say, they are mutually interchangeable; the position of the one point governing the location of the other; rays coming from B focus at b; and conversely, rays emanating

from b would focus at B; and as B approaches the lens to c, the image b retreats towards c on the other side.

There are two other positions requiring special notice, namely, the two secondary foci, so called because they are "secondary" in importance; the principal foci being first. These points are two conjugate foci situated at corresponding distances (equal to twice the focal length), on each side of the

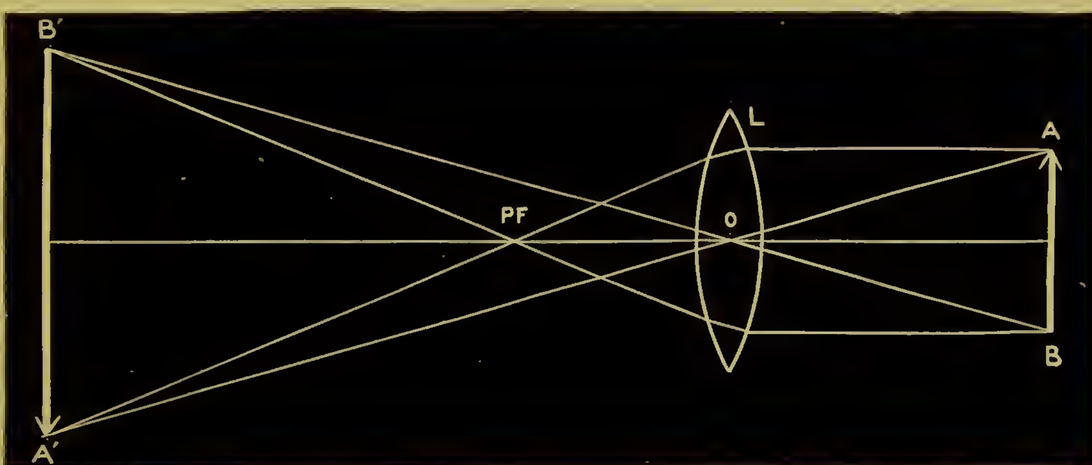


Fig. XX.

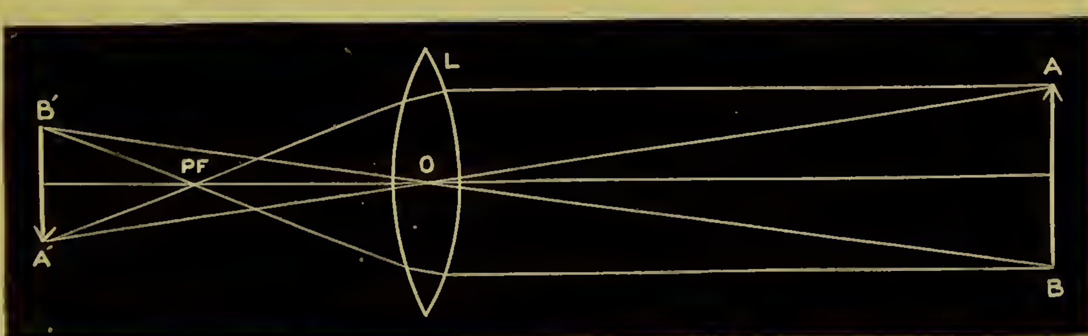


Fig. XXI.
A B Object. B′ A′ Image. L Lens. O Optic Centre.
P F Principal Focus.

convex lens; and an object placed at one point has its image at the other, which is of the same size as the object. It will be noticed later that the secondary foci of a convex lens resemble in this respect the "centre of curvature" of the concave mirror. A simple method of drawing the position and size of an image formed by a convex lens is as follows: (see also Figs. XX. and XXI.)

Draw, from both extremities of the object, a straight line passing through the optical centre of the lens, and produce same on the other side. Then draw a line parallel to the principal axis, from the top and bottom of the object to the lens, and continue, through the principal focus, until they intersect the lines first drawn (the secondary axes). The image is formed at the points of intersection. If the lens is concave, follow the same method, but since the rays, if prolonged, will not intersect the secondary axes, continue them backwards in the direction of the principal focus until they do (see Fig. XXII.).

From an optical standpoint, the eye may be considered as a dioptric system (a system of lenses), made up of several refractive media. According to Gauss, in such a system there

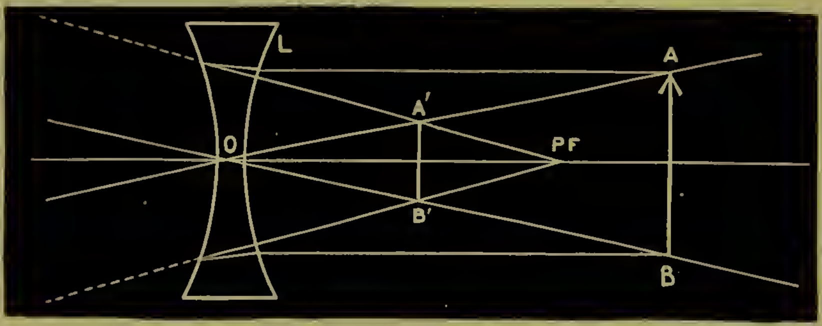


Fig. XXII.

A B Object. A′ B′ Image. O Optic Centre. L Lens.
P F Principal Focus.

are six cardinal (or chief) points, which bear a definite relation to each other. These may be described as follows:—

Two principal foci: All rays passing through the first principal focus are parallel to the axis after refraction, and every ray parallel to the axis before refraction passes through the second principal focus after refraction.

Two principal points: All rays which travel through the first point before refraction afterwards pass through the second; and every ray which passes through any point of a plane elevated on a perpendicular axis from the first principal point (the first principal plane) passes through the corresponding

point of a similar plane, raised upon the axis at the second principal point (the second principal plane). These points are those on the principal axis from which the focal lengths are measured.

Two nodal points : These correspond to the optical centre of the two principal planes just mentioned.

The distance of the first principal point from the first principal focus is called the anterior focal length; and the posterior focal length is the distance of the second principal point from the posterior principal focus.

Tscherning, applying the theory of Gauss mentioned above, has calculated the optic system of the eye, presenting us with the following figures :—

Position of the first principal point....	1·54 m/m.
Position of the second principal point	1·86 m/m.
Position of the first nodal point	7·30 m/m.
Position of the second nodal point....	7·62 m/m.
Position of the anterior focus	15·59 m/m.
Position of the posterior focus	24·75 m/m.
Anterior focal distance	17·13 m/m.
Posterior focal distance	22·89 m/m.
Refracting power	58·38 D.

Listing has given the following measurements for the cardinal points in an ideal eye, measured from the centre of the Cornea in millimetres :—

Anterior principal focus	12·8326 m/m.
Posterior principal focus	22·6470 m/m.
First principal point	2·1746 m/m.
Second principal point....	2·5724 m/m.
First nodal point	7·2420 m/m.
Second nodal point	7·6398 m/m.
Anterior focal length	15·0072 m/m.
Posterior focal length	20·0746 m/m.

The other measurements of such an eye are :—

Radius of curvature of anterior surface of Cornea	8 m/m.
Radius of curvature of anterior surface of Lens	10 m/m.
Radius of curvature of Posterior surface of Lens	6 m/m.
Index of refraction of Aqueous Humour....	1·3379.
Index of refraction of Crystalline Lens	1·4545.
Index of refraction of Vitreous Humour....	1·3379.

Listing constructed what is known as the *reduced eye*, by still further simplifying the optical constants, and assuming that the two principal points and two nodal points respectively are identical. The principal point being 2·3448 m/m. and the nodal point 7·4969 m/m behind the Cornea ; the eye having an anterior focal length of 15 m/m., and a posterior focal length of 20 m/m. Thus, for rays parallel on entering the Cornea the dioptric value of the eye equals + 50·D ($\frac{1000}{20}$) ; and for rays parallel in the Vitreous Humour it is somewhat greater, namely, + 66·D ($\frac{1000}{15}$). The lens or refractive surface of this "reduced" eye has a radius of 5 m/m., and is 3 m/m. behind the Cornea ; and the index of refraction for the combined media is taken as 1·3379.

If one is familiar with the cardinal points mentioned above, the course of rays entering the eye can be easily traced, see Fig. XXIII., which shows the direction of rays travelling from an object to the Retina of such a "reduced" or "schematic" eye. PA represents the principal axis, and OO′ the object. A ray from O, passing through the nodal point to I, is the secondary axis, to which other rays emerging from this same point converge after refraction at the dioptric surface at the (merged) principal points shown at XX. Rays from the other extremity of the object travel in the same way to a focus at I′ ; as do also all rays of light emerging from other points between O and O′ ; so that a perfect inverted image is formed on the Retina. The angle included between the secondary axes, OI

and o′ɪ′, is called the visual angle; and upon the size of this angle depends the magnitude of the retinal image.

The visual angle increases with the size of the object for the same distance; and for the same object the visual angle diminishes as the object recedes. The size of the retinal image alters with the visual angle; and this latter, in its turn, is dependent upon the size and distance of the object. This angle therefore assists us in our mental estimation of size and position.

The relative size of image and object are as their respective distances from the optical centre of a lens; in the case of the

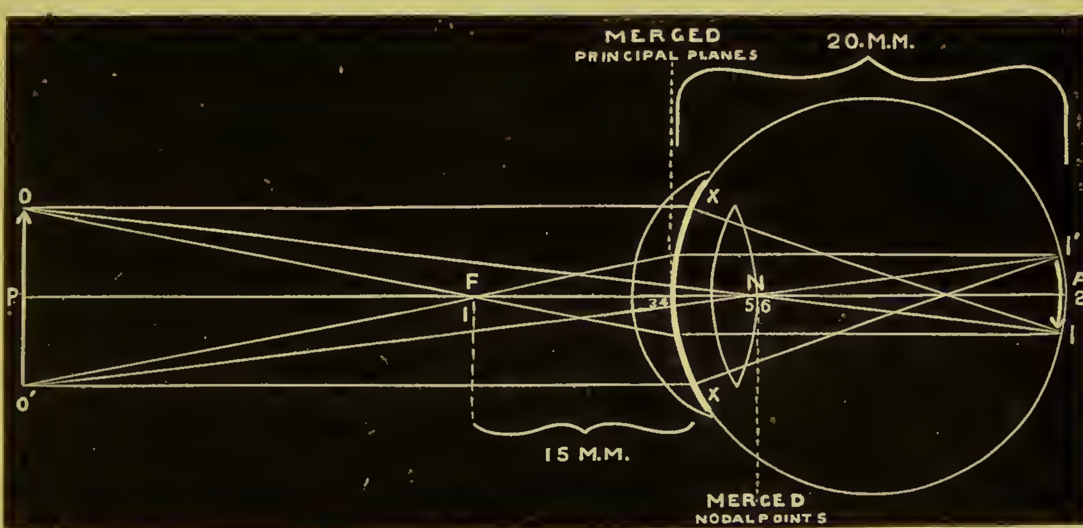


Fig. XXIII.

The *figures* indicate the cardinal points according to Gauss as follows:—

1. First principal focus.
2. Second principal focus.
3. First principal point.
4. Second principal point.
5. First nodal point.
6. Second nodal point.

eye the nodal point answers to the optical centre; therefore to estimate the size of the retinal image, we take our distances from this point, which was stated to be 7 m/m. back of the Cornea and 15 m/m. in front of the Retina. Suppose the object to be 17 m/m. square, and situated at 6 metres in front of the eye, the retinal image would be $\frac{15}{6000}$ of 17, or a trifle more than ·04 m/m. A rule to remember in this connection is, to multiply the height of the object by the distance of the

Retina from the nodal point, and divide by the distance the object is from the eye; being careful, however, that the size of the object and its distance from the eye are expressed in similar terms—both in millimetres or in centimetres, as the case may be.

A lens is a part of any refracting substance, having on both sides polished surfaces, which have the property of changing the direction of rays of light traversing it; and, as before stated, may be either of two kinds, spherical and cylindrical.

A spherical lens is one which refracts rays of light falling upon it, equally in all directions; *i.e.*, brings them to a focus at a point. They may be convex or concave. Convex lenses are sub-divided into three different forms, viz. :—

(A) Double or bi-convex; equally convex on either side.

(B) Plano-convex; convex on one side, and plane on the other.

(C) Periscopic or Meniscus Convex (or concavo-convex), which are convex on one side, and concave on the other, the convexity having the predominance.

Spherical concave lenses are also—

(D) Double or bi-concave; that is, equally concave on either side.

(E) Plano-concave; concave on one side, and plane on the other.

(F) Periscopic or Meniscus Concave (or convexo-concave), which are concave on one side, and convex on the other; but in these lenses the concavity preponderates (see Fig. XXIV., A to F).

Periscopic lenses are useful, as they enable the wearer to see more clearly in the lateral movement of his eyes; that is,

they allow of a larger field of vision. Plano-spherical lenses are never used in spectacles, on account of the little advantage they possess over the bi or double lenses, and also they are much more expensive. The kind of lenses most in use are the bi-spherical.

Cylindrical lenses (commonly called "cylinders") are segments of cylinders, one surface of which is usually plane,

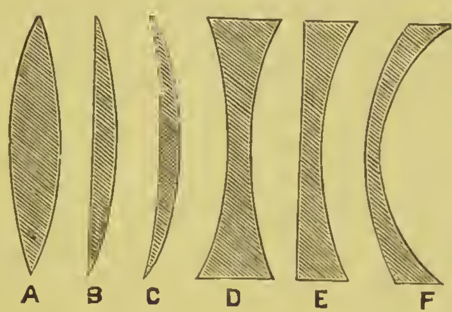
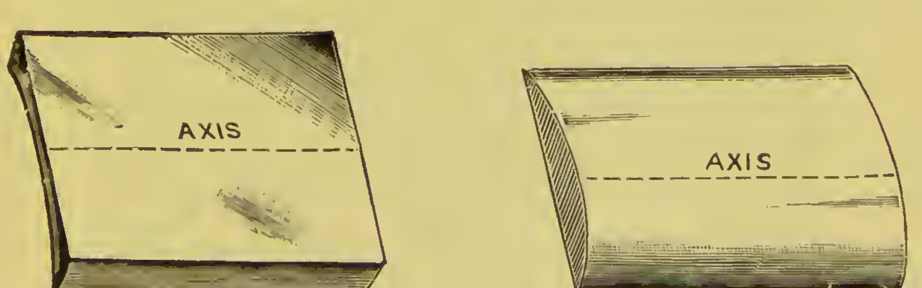


FIG. XXIV.

and the other may be either convex or concave. A "cylinder" is a lens which refracts rays falling upon it on either side of its "longitudinal axis," which is parallel to the axis of the cylinder of which it forms part; that is, in the direction of its axis it is plain glass, because this direction is parallel to the opposite surface, which, as before mentioned, is without curvature; and therefore rays of light in passing through the lens in this



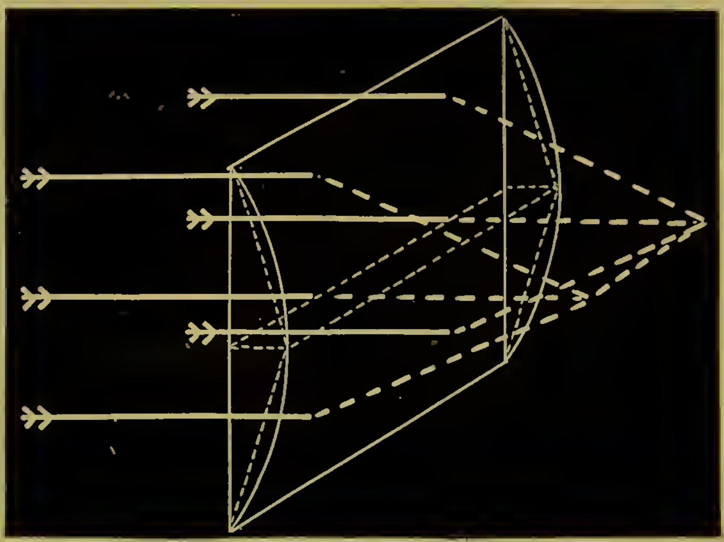
CONCAVE CYLINDRICAL LENS. CONVEX CYLINDRICAL LENS.

FIG. XXV.

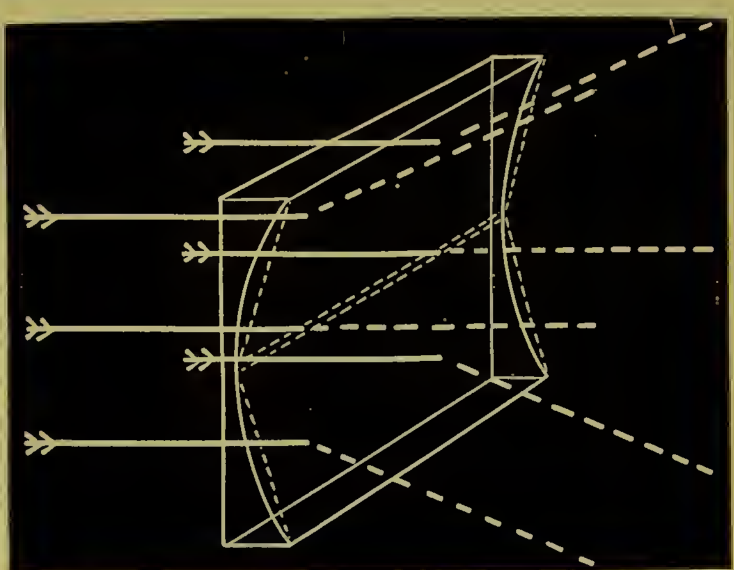
meridian, undergo no refraction. But all parallel rays passing on either side of this longitudinal axis will be made convergent or divergent, according to whether the cylinder be convex or concave (see Fig. XXV.)

Prisms are utilised in studying and explaining cylindrical

lenses, as well as spherical (see page 25). In this case, however, the prisms are ranged towards a central line called the axis (not a point, as with spheres); their bases being



Convex Cylindrical Lens.



Concave Cylindrical Lens.
Fig. XXVI.

towards it in convex, and the apices when concave. This will assist you to understand their action better on rays of light; the rays being refracted in the direction of the bases, except

at the *line of junction* of the opposing prisms, where the light passes straight through, owing to the parallelism of the opposite surfaces (see Fig. XXVI.)

Strictly speaking, a cylindrical lens refracts rays of light in every meridian *except* in the direction of the axis; but the amount of refraction is greater, the nearer the rays of light fall on the lens to the meridian farthest from the axis or plane glass; *i.e.*, at right angles to it. But for our purpose it will suffice to say that those rays falling on the lens at right angles to the axis undergo deviation.

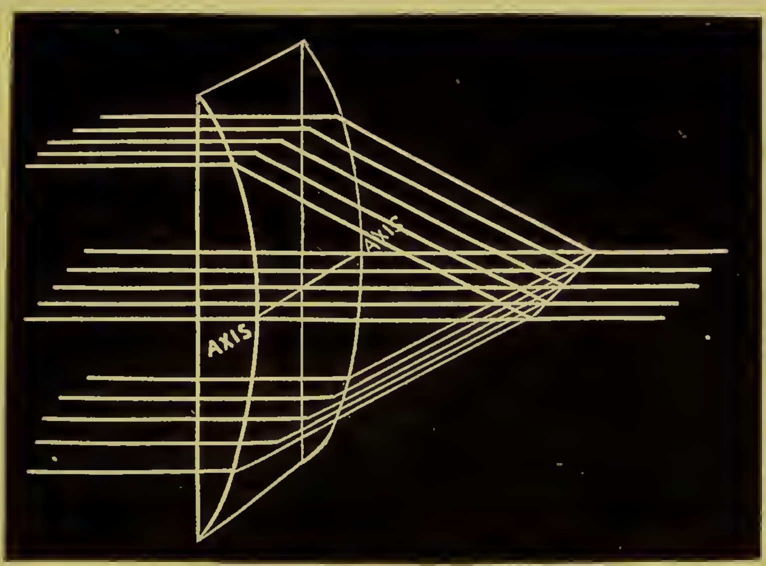


Fig. XXVII.

Showing refraction of parallel rays after traversing a convex cylindrical lens.

These lenses are used in the correction of Astigmatism. In trial cases the axes of cylindrical glasses are generally indicated by a portion of the lens on each side being ground parallel to the axis; and the exact position shown by a diamond scratch at either end of the lens. However, when a cylindrical combination is made up (say for a patient's use), they cannot be distinguished from an ordinary spherical lens by a casual glance; but, of course, can be readily recognised by

looking through the lens at an object, or by neutralizing it. (This will be explained in the next chapter).

NUMBERING OF LENSES.

There are two systems of numbering lenses; one called the inch, and the other the metric or dioptric system.

According to the inch system, a lens of one-inch focus is taken as the standard; and this unit being the strongest lens, all others are weaker, and must necessarily be expressed in fractions. A lens having a focal length of two inches—*i.e.*, twice the focal length of the unit—would possess one-half its strength, and would be expressed by the fraction $\frac{1}{2}$. A lens having a focal length of eighty inches—that is, eighty times the focal distance of the unit—would have only one-eightieth of its refracting power, and would be expressed by the fraction $\frac{1}{80}$. Thus it is seen that all the various lenses weaker in proportion are represented by corresponding fractions; and the denominator of the fraction represents the focal distance and refracting power. The principal objection to this system is when the necessity arises to combine two lenses of different power together; as the addition has to be made entirely in fractions. For example, when a twenty-inch lens and a thirteen-inch lens have to be combined, one has to deal with their refracting powers. In the case just mentioned, the refracting powers would be one-twentieth and one-thirteenth; then $\frac{1}{20} + \frac{1}{13}$ is the problem to be worked out, which is scarcely a thing to be done "in the head"—especially as this kind of calculation is necessary whilst one is testing a patient. We reduce them to a common denominator, and have $\frac{1}{20} = \frac{13}{260}$ and $\frac{1}{13} = \frac{20}{260}$. Then $\frac{13}{260} + \frac{20}{260} = \frac{33}{260}$ which equals about 7·9 inches, which for convenience we will call 8 inches. This kind of calculation occurs frequently in the daily experience of the refractionist, and forms the greatest objection to the inch system; besides which, the frequent occurrence of this is not likely to have a very beneficial effect upon one's temper.

Another objection is that the intervals between the lenses are not regular. For example, the difference between a one-sixth and a one-seventh lens is much greater than between one-thirteenth and one-fourteenth lens, and so on; and again, the inch measurement varies in different countries; the French inch being slightly longer than ours. For the reasons just enumerated, I advise students to disregard this system entirely in favour of the metric, which is explained below.

The dioptric or metric system has for its unit a lens having a focal length of one metre (or 39·37 inches); *i.e.*, a lens which brings parallel rays to a focus at that distance, which is called one dioptre (abbreviated "1D."). (The word "dioptre" means "to see through"). In this system, then, a weak, instead of a strong, lens is used for the unit; and as the majority of lenses are stronger than this, their refracting power is represented by whole numbers. A lens three times the strength of the unit is a three dioptre, or 3D; a lens six times the strength, a six dioptre, or 6D.; and so on.

However, it is found that for practical purposes there is need of lenses weaker than 1D., for which reason we are furnished with three intermediate lenses between the dioptres and the same weaker than the unit—viz., 0·25D., 0·50D., and 0·75D., the focal length of which are respectively 4 metres, 2 metres, and $1\frac{1}{3}$ metres. It is evident then, in this system, that the intervals are equidistant, and the combinations of lenses much simplified; in fact, any combination can be reckoned mentally without much difficulty. For instance, combine 1·75 and 2·25, and it will give us 4D.; or 0·50 added to 3D. is 3·50; or take 1·50D. from 6D., and it leaves 4·50D. Hence this system does away with the principal objections to the inch system of numbering lenses, and is now in more universal use than the other. There are other sub-divisions besides 0·25, 0·50, and 0·75—namely, 0·12D., 0·37D., 0·62D., 0·87D.; but these are never required, because, as all of my readers will know, in Hypermetropia you slightly over-correct

the defect, and in Myopia you slightly under-correct it. Therefore, for example, if + 1·37 gave the best vision, you should prescribe + 1·50; or if −0·87 seems necessary, you give −0·75. Consequently, with the three decimals, ·25, ·50 and ·75, you have all the strengths you will ever find necessary. Convex lenses are, as a rule, written with the algebraical sign + before them; thus, + 0·50D., + 7·25D., + 1·75D.; and concave (or minus) lenses usually have the sign − in front, thus, − 0·25D., − 3·25D., − 8·50D.

Now that we have considered thoroughly the two methods of numbering lenses, it is imperative that you should be able to reduce the inch into the metric system, and *vice versâ;* as although the latter is now used almost universally, yet you may have a prescription given you which is written in inches.

The metre equals 39·37 English inches; but, for the sake of convenience, we will regard it as 40 inches—then we accept as the equivalent of 1D. a lens having a focal length of 40 inches. In converting one system into the other, remember this simple rule: *to find the number of dioptres in a given number of inches, divide the inches into* 40*; and to find the number of inches in a known number of dioptres, you simply divide* 40 *by the number of dioptres.* Example:—How many dioptres in 10 inches? Divide 10 into 40 ($\frac{40}{10}=4$), and the result is 4 dioptres. To find how many inches in 3 dioptres, divide 3 into 40, and the result is 13 inches ($\frac{40}{3}=13$). Of course, in this example, 3 goes into 40, 13 and a fraction over—but it is so inconsiderable a fraction that it escapes notice; and for all practical purposes 3D. = 13 inches, and 13 dioptres would equal 3 inches.

The following table shows the metric system and its equivalents, both in inches and centimetres. This table not only now deserves the careful attention of the reader, but should always be kept in a convenient place for reference; and I would put forth as a suggestion, that there is no better place than the memory.

TABLE OF METRICAL SYSTEM.

WITH EQUIVALENTS IN INCHES AND CENTIMETRES.

Dioptres.	Inches.	Centimetres.
0·25	160	400
0·50	80	200
0·75	52	130
1·00	40	100
1·25	31	77
1·50	26	65
1·75	22	55
2·00	20	50
2·25	17	43
2·50	16	40
2·75	14	35
3·00	13	33
3·50	11	27
4·00	10	25
4·50	9	22
5·00	8	20
5·50	7	17
6·00	6½	16
6·50	6	15
7·00	5½	14
7·50	5¼	13
8·00	5	12½
9·00	4½	11
10·00	4	10
11·00	3½	9
12·00	3¼	8
13·00	3	7½
14·00	2¾	7
16·00	2½	6½
18·00	2¼	6
20·00	2	5

As the metric system is now so commonly used amongst refractionists, and is in every way preferable, not only for measuring the strength of lenses, but also when taking the near point and other necessary measurements, the calculations used later in this book will be all on the metrical system. If you wish to convert centimetres into dioptres, divide them into 100, as 1D. = 100 centimetres (see table); and to reduce dioptres into centimetres, it is only necessary to divide the dioptres into 100.

Before closing this portion of the chapter, it would be well to say a few words about the numbering of prisms. A prism (see Fig. XXVIII.) is a wedge-shaped piece of glass, having two of its sides inclining to one another, meeting at what is called

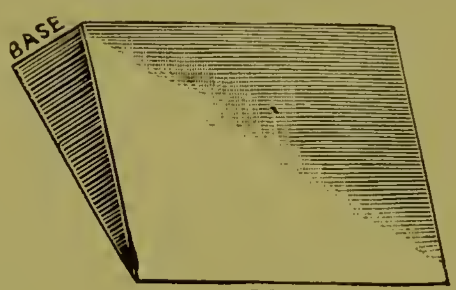


Fig. XXVIII.

the apex—the thick portion of the prism is termed the base (see Fig. XXVIII.). There are usually about ten of these prisms in a trial case, numbering from one to fifteen or twenty. They should seldom, however, be prescribed for constant use; but are useful to measure the amount of any existing insufficiency of one or more of the extra-ocular muscles (*i.e.*, either the Recti or Oblique), or for the purpose of exercising them (*vide* chapter on Strabismus). Prisms, like ordinary lenses, are also numbered in several ways: by prism-dioptres (abbreviated$^{\Delta}$), by degrees of refracting angle (°)—that is, the angle formed at the apex by the sides of the prism—and by the angle of deviation (°D.)—the former now being adopted in all up-to-date trial cases, although the use of degrees is still adhered to by the old school of opticians, for which reason I give both methods.

The angle of deviation (°D) is equal to about twice the power of the prism-dioptre and degree, but is seldom, if ever, employed now for numbering prisms.

One prism-dioptre, abbreviated 1^{Δ}, is represented by a prism which, at a distance of one metre, causes an apparent displacement of an object one centimetre; and is the unit used

Fig. XXIX.

in the numbering of prisms (see Fig. XXIX.). A 3^{Δ} prism would be three times the strength of the unit, and, therefore, would apparently displace the object at a distance of one metre three centimetres. The displacement produced by a prism dioptre is then just equal to one per cent. of the distance at which the object is situated from the prism; so that at six metres, the apparent position of an object would be 6 c/m. from its actual location; and at a distance of one half-metre,

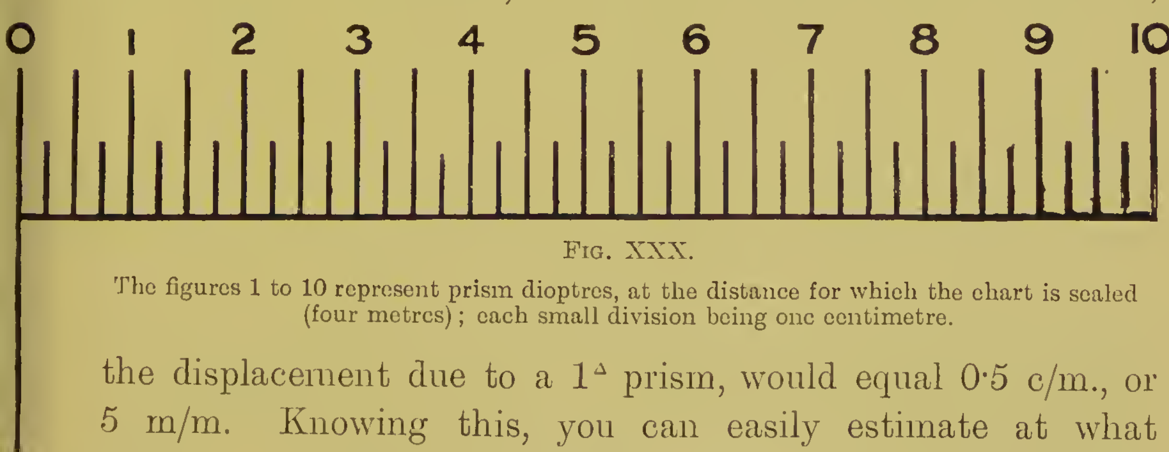


Fig. XXX.

The figures 1 to 10 represent prism dioptres, at the distance for which the chart is scaled (four metres); each small division being one centimetre.

the displacement due to a 1^{Δ} prism, would equal 0·5 c/m., or 5 m/m. Knowing this, you can easily estimate at what distance you should stand from a given prism scale, when measuring in prism dioptres. If the divisions of your chart measure 3 c/m. each, you know that it is scaled for three metres; if the divisions are 1 c/m. each, it is scaled for one metre; and so on. (See Fig. XXX.) And conversely, if you

are standing six metres from a 3-metre scale, and the displacement due to your prism is two divisions (which equals 6 c/m.), representing 2^{Δ} at three metres, you must halve your result, making it 1^{Δ}. (The displacement here is 6 c/m., which at six metres is just 1% of the distance.) If you had been standing at one metre from the same scale, and the displacement equalled three divisions, your prism would be 9^{Δ}—the amount of displacement being nine times that of the unit, or 9% of the object-distance. The prism-dioptre is slightly more powerful than the degree (refracting angle, abbreviation for which is °), and a little more than half the power of one degree of deviation. See following table:—

1^{Δ}	=	1·1°	=	0·57°D
2^{Δ}	=	2·2°	=	1·14°D
3^{Δ}	=	3·3°	=	1·71°D
4^{Δ}	=	4·4°	=	2·28°D
5^{Δ}	=	5·5°	=	2·85°D
6^{Δ}	=	6·6°	=	3·42°D
7^{Δ}	=	7·7°	=	3·94°D
8^{Δ}	=	8·8°	=	4·56°D
9^{Δ}	=	9·9°	=	5·13°D
10^{Δ}	=	11°	=	5·70°D
12^{Δ}	=	13·2°	=	6·84°D
15^{Δ}	=	16·5°	=	8·55°D
20^{Δ}	=	22°	=	11·40°D

(NOTE.—This table, although sufficiently accurate for working purposes, is not absolutely true, particularly for the higher powers, but the error is so small as to be negligible.)

The above table is compiled on the supposition of the glass having a refractive index of 1·52, that generally employed for spectacle lenses.

The relation which the three methods of numbering prisms bear to one another is as follows; and it will be seen that it is only necessary to multiply the number given by the desired

equivalent, in order to transpose into either of the other systems:—

$$1^{\Delta} = 0{\cdot}57^{\circ}D = 1{\cdot}1^{\circ}$$
$$1^{\circ} = 0{\cdot}52^{\circ}D = 0{\cdot}9^{\Delta}$$
$$1^{\circ}D = 1{\cdot}745^{\Delta} = 1{\cdot}9^{\circ}$$

Example (a): Express 3^{Δ} in terms of refracting angle and angle of deviation.

$$3 \times 1{\cdot}1 = 3{\cdot}3^{\circ}; \text{ and } 3 \times 0{\cdot}57 = 1{\cdot}71^{\circ}D.$$

Example (b): How many degrees of refracting angle and prism dioptres has a prism of 2°D?

$$2 \times 1{\cdot}9 = 3.8^{\circ}; \text{ and } 2 \times 1{\cdot}745 = 3{\cdot}49^{\Delta}.$$

Example (c): Convert 6° into prism dioptres and degrees of deviation.

$$6 \times 0{\cdot}9 = 5{\cdot}4^{\Delta}; \text{ and } 6 \times 0{\cdot}52 = 3{\cdot}22^{\circ}D.$$

There is yet another method of expressing the strength of prisms—viz., the centrad (1^{∇})—but this is practically the same strength as the prism-dioptre, and is, therefore, hardly worthy of consideration, especially as the prism-dioptre, with the occasional occurrence of the degree (°), is now universally employed.

REFLECTION.

Reflection is the rebounding of rays of light on striking a reflecting surface. All visible objects that are not self-luminous are reflecting bodies; because, unless the light was reflected from them to our eyes they would not be visible. The original ray, that is, the one approaching the surface, is called the "incident ray"; that one rebounding from the reflecting surface is termed the "reflected ray." Reflection then takes place from any visible object, although we, in our present studies, are only interested in reflection from mirrors. These are of two principal kinds, plane and curved; the latter being divided into concave and convex. The laws governing reflection are two.

Rule I. *The angle of incidence is always equal to the angle of reflection.* That is to say, that if a ray of light strikes the surface at an angle of 35° with the perpendicular, it will rebound at an angle of 35° on the other side of the *perpendicular* or normal. This is a line meeting the mirror (or in fact, any surface) at right angles to it; and the perpendicular to any point of a spherical surface is a line drawn from that point to the centre of curvature of the mirror.

Rule II. *The incident, the normal, and reflected rays are all in the same plane, which is perpendicular (or at right angles) to the reflecting surface.* What is precisely meant by

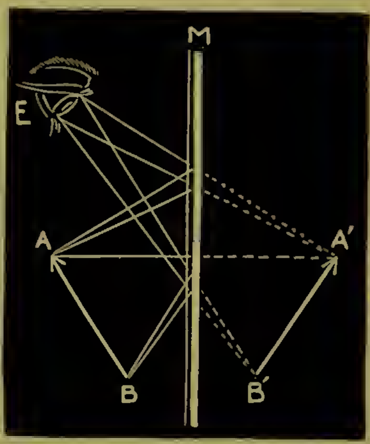


Fig. XXXI.

AB Object. A′B′ Image. E Eye. M Mirror.

this is, that the reflected ray will be exactly on the opposite side of the perpendicular from the incident ray; it does not swerve to either side.

Rays of light reflected from a plane mirror, travel in the same state, after reflection, as they approached the surface; that is, as a *beam* or a *converging* or *diverging pencil*, as the case may be. The image formed by a plane mirror is virtual, erect, of the same size as the object, and at the same distance behind the mirror as the object is in front of it (see Fig. XXXI.). A plane mirror produces an image the same, then, in all particulars as the object, except direction—all reflected images, no matter from what kind of mirror, undergo lateral inversion.

A simple way of drawing the reflected image formed by a plane mirror, is that followed in Fig. XXXI., and is easily remembered :—

Draw the object AB, and at an equal distance on the opposite side of the mirror M (within it), draw image A′B′ ; from A′, trace a diverging cone of light to the eye at E, and from A extend two lines, so as to meet these rays at the surface of the mirror. Treat B′ and B similarly, and you have your completed drawing.

The focus is where two or more rays meet after reflection (or refraction) ; and in the case of a concave mirror, this is always found on the same axis as the object, whether principal or secondary. Parallel rays falling on a concave mirror are reflected as convergent rays, meeting at a point on the principal axis called the "principal focus," which is half-way between the surface of the mirror and its centre of curvature (or concavity).

If a ray strikes the mirror exactly perpendicular to its surface, it returns along the same path that it came. This happens when the luminous point is at any point of the normal, and when it is situated at the centre of curvature the point is its own image. If the ray strikes the mirror obliquely, then it is reflected so that it forms an angle of reflection equal to the angle of incidence (see Rule I.). In a concave mirror, if the object is at *infinity*, the image will be real, inverted and smaller than the object, and situated at the *principal focus* of the mirror. If the object is at some finite distance beyond the *centre of curvature*, the image will be real, inverted and smaller than the object, and situated between the principal focus and centre of curvature. If the object is at the centre of curvature, the image will be real, inverted, the same size as the object, and situated at the same place.

If the object is between the centre of curvature and principal focus, then the image will be real, inverted, larger than the object, and situated at a finite distance beyond the

centre of curvature. If the object is at the principal focus, there will be no image formed at all; since the rays, after reflection, are rendered parallel, and so never meet. When the object is situated between the principal focus and the mirror,

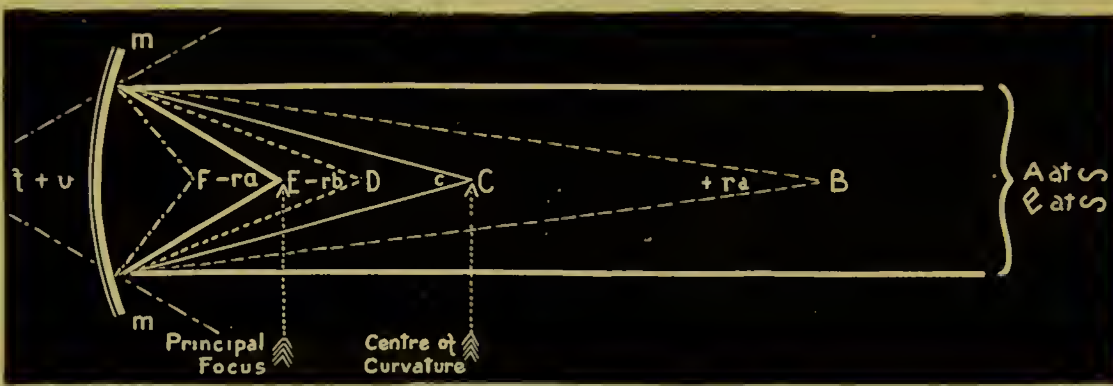


Fig. XXXII.

Capitals = Position of Object. Small letters = Position of Image.
r = Real and inverted. + = Enlarged. V = Virtual and erect. – = Diminished.

the image is virtual, erect, enlarged, and at the back of the mirror; and as the object approaches the mirror, the image diminishes until the mirror is reached, when the object and image are of one size and at the same place.

It is seen, therefore, that a concave mirror forms either a

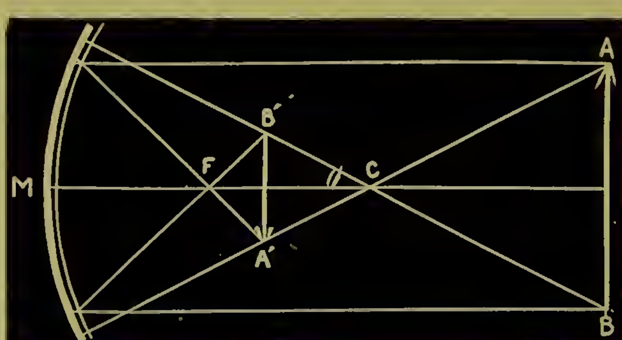


Fig. XXXIII.

AB Object. A′B′ Image. C Centre of Curvature. F Principal focus. M Mirror

real or virtual image, according to the position of the object—the real image gradually increasing in size as the object approaches the principal focus; when this is reached no image

is formed, but within this distance an enlarged, upright, virtual image is formed, which diminishes in size as the object still further approaches the mirror. Unreal or virtual images, it will be noticed, are always upright, and real ones are always inverted. The longer the radius of curvature of the mirror, the larger the image; the shorter the radius of curvature, the smaller the image.

Images formed by convex mirrors are always virtual, erect, smaller than the object, and situated at the back of the mirror, but never further back than the principal focus. When the object touches the surface of the mirror, the image is of the same size and situated at the same place. Fig. XXXII. graphically illustrates the foregoing remarks respecting concave mirrors. The capital letters denote the position of the

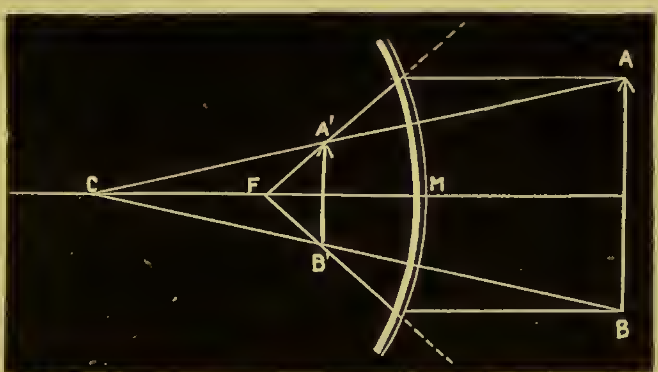


FIG. XXXIV.

AB Object. A'B' Image. C Centre of Curvature. F Principal focus. M Mirror.

object, and the corresponding small letters show the location of the respective images. Luminous point B and image b are conjugate foci; that is, the one point is the focus of the other, and they are mutually replaceable. As in convex lenses we find the secondary foci at twice the distance of the principal focus, so in reflection is the centre of curvature twice as far from the mirror as the principal focus. Another point of similarity worth mentioning is, that the image of an object situated at the centre of curvature is the same size as the object, and at a corresponding distance from the mirror.

To draw an image formed by a concave mirror, draw a line from each extremity of the object through the centre of curvature to the mirror; then draw a line parallel to the principal axis from each end of the object to the mirror, and continue same in the direction of the principal focus, passing through this point until they intersect the lines first drawn (see Fig. XXXIII.).

In convex mirrors, do exactly as described above; only since the lines after reflection do not intersect, prolong them backwards (refer to Fig. XXXIV.).

CHAPTER III.

NEUTRALIZING AND DECENTRATION.

Now that the reader is familiar with the different kinds of lenses, and the properties of each, it will not be out of place if we devote a little time to the neutralization of lenses, and explain the various methods by which he may distinguish the kind and strength of any lens or combination of lenses that may come into his hands.

The first step is to be able to *distinguish between a spherical and a cylindrical lens.* This is accomplished by viewing, through the lens we wish to test, some object; for preference, a perpendicular straight line. If, on rotating the lens, the line is stationary, it signifies that the lens is spherical; if, on the other hand, it is a cylinder, the portion of the line seen through the glass will appear to twist round as you rotate the lens, changing from the vertical to an oblique direction (see Fig. XXXV.).

When one becomes a little expert in this work, any object about the room may be used instead of the straight line; for instance, a picture on the wall, or the corner of a desk will be equally suitable, as the distortion due to the cylindrical element in a lens combination is sufficiently noticeable to be immediately recognized.

To distinguish between a convex and a concave lens.—On looking through a convex lens at an object, and moving the lens from right to left, or up and down, there will be an apparent movement of the object *against* that of the lens; *i.e.*, if the lens is moved to the right, the object appears to go to

the left, and the reverse; or if the lens is raised, the object will appear to fall. If the lens is concave, the object will appear to move in the *same* direction as that in which you move the lens; that is, if the lens be moved to the left, the object will move to the left also.

In order to make this explanation more lucid, we must try and consider a convex lens as being composed of two prisms with their bases together, as in Fig. XIII. cx (p. 25). On moving a convex lens down before the eye, we view the object through the top prism; that is, a prism with its base down; and the natural consequence is that the object is deflected upward

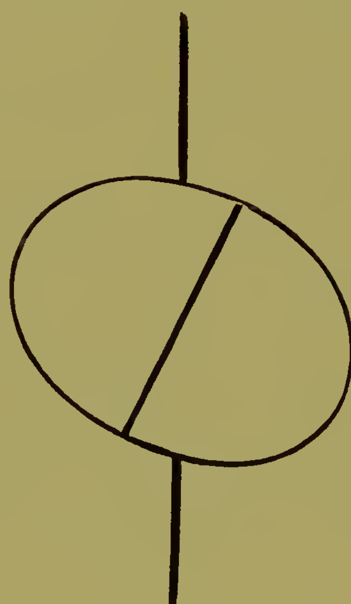


Fig. XXXV.

towards the apex. Again, on moving this lens upward before the eye, we look through the lower prism; that is, a prism base up; and naturally the apex is down, and the apparent movement of the object viewed through the lens is also downward. Thus is explained the phenomenon respecting the movement of an object seen through a convex lens which is moved in various directions before the eye.

On referring to the illustration of a concave lens on p. 25 (Fig. XIII. cc), it is obvious that its action must be the reverse of the above. When this lens is raised, we look through the

lower prism, which has its base downwards, and its apex upwards, so that the object seen is shifted in this direction. And again, on lowering the lens, our line of vision passes through the top portion of the lens which constitutes a prism base up, so that the object seems to move from its original position downwards; that is, in the direction in which the lens is moved.

The above is the quickest and most accurate method of distinguishing between convex and concave lenses, and is much to be preferred to the old habit of seeing whether a lens magnifies or diminishes the apparent size of the objects observed through it. One can in this way also obtain a rough approximation of the strength of a lens, as the quicker the apparent movement of the object, the stronger the lens. However, to be able to obtain anything like an accurate guess only comes by constant practice.

Sometimes, in weak lenses, the behaviour of the object as above described, is more readily seen by holding the lenses further from the eye. Care should be taken, if the lens is convex, not to hold it further away than its focal length; or the movement of the object will be contrary, *i.e.*, with the lens, instead of against it.

To ascertain the strength of an unknown lens.—Place the lens you are testing in contact with one of opposite power (that is to say, if the lens of which you desire to know the strength is convex, place in opposition to it a concave lens of known power), and observe some object as before. If the two lenses exactly neutralize, there will be no apparent movement of the object in any direction in which you move the lenses; if, however, there is movement, and it is still against that of the lenses, it shows that there is still a predominance of the convexity, and a stronger negative or concave lens is to be tried, until no movement whatever is discernible; and this lens will measure the strength of the one tested. If, on the other hand, when the two lenses are together, the movement of the object

is *with* that of the lenses, it is manifest that the concave lens is the stronger, and consequently a weaker one is chosen, until there is no motion of the object viewed through them.

The inference to be drawn from the above is, that if two lenses of the same focal strength, but of opposite power, are placed in contact, they will neutralize each other; or in other words, the convexity of the one will nullify the effect of the concavity of the other, giving a "plano" or plane lens. For instance: a + 1D. will neutralize a − 1D.; and a + 3·50D. neutralizes a − 3·50D.; or − 1·25D. a + 1·25D.; and so on.

To determine the direction of the axis of a cylinder.—Hold it between the eye and some straight object, and rotate it; and

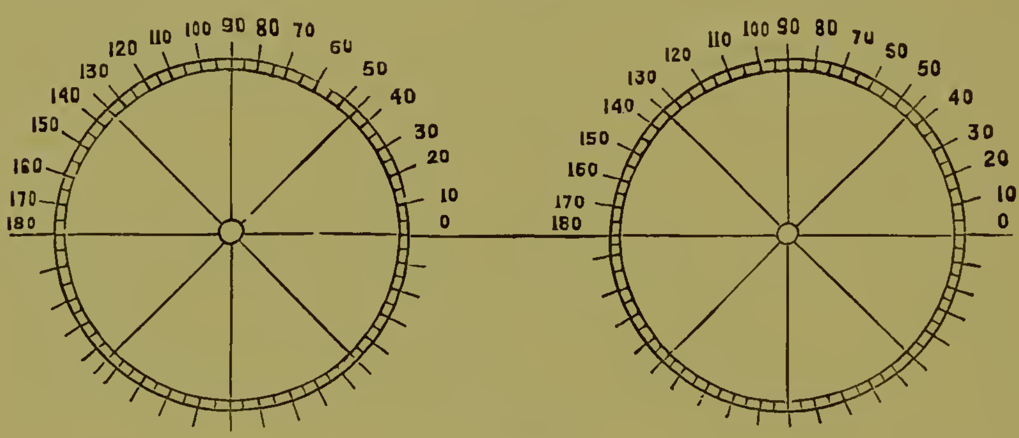


Fig. XXXVI.

the object thus seen will appear distorted in shape, except when the axis, or the meridian at right angles to the axis, corresponds to the true position of the line viewed. When the position is found, move the lens sideways from right to left, or up and down, and the meridian where there is no motion of the object is the axis.

In the case of a sphero-cylinder, there will be a motion of the object in both these directions, but the cylindrical axis will correspond to the meridian in which there is the least movement. Now, having found the direction, draw a line on the lens, corresponding to the axis, and then place the lens on a card (see illustration) on which are drawn radiating lines;

making sure that the centre of the lens is over "O" in the centre of the figure; and read the direction of the axis from the numbers; the other principal meridian (where the power is) being at right angles or 90° from this meridian.

To ascertain the strength of simple cylinders and sphero-cylinders.—On moving a simple cylinder between the eye and an object, there will be one meridian in which there is no movement of the object, and this is the axis. If, for example, the lens you are testing is a convex cylinder, place in front of it, and in contact with it, a minus cylinder; taking care that the axes of both lenses coincide. Now increase the strength of the concave cylindrical lens, until there is no movement of the object; and the power of the concave cylinder represents the strength of the convex one you are testing.

Sphero-cylinders (that is, made up of a sphere and a cylinder) will cause the object to move in all meridians; but in one direction there will be the least, and in the other, at right angles (or 90°) to it, the greatest movement. First locate the two principal meridians; that is, the axis and the direction at right angles to it as described previously. Neutralize the motion in the direction corresponding to the axis, with a sphere of opposite power; in which way you reduce the compound lens to a simple cylinder. Now, still keeping these two lenses together, place a cylinder in front of the combination, until you obtain one that stays all motion in the other meridian. Be careful that the axis of this cylinder is in the meridian in which you neutralized all movement with the spherical lens. For example: If a + 1 sph. $\bigcirc$ (combined with) + 1 cyl. ax. 180° be held in front of a − 1 sph. $\bigcirc$ − 1 cyl. ax. 180°, they will neutralize each other; and + 2·75 cyl. ax. 90° will neutralize a lens of − 2·75 ax. 90°. If a compound lens requires + 3·75 sph. $\bigcirc$ + 1·25 cyl. ax. 180°, to stay all movement of the object viewed through it, we know it is a −3·75 sph. $\bigcirc$ − 1·25 cyl. ax. 180°.

In addition to being able to find the strength of any

unknown lens by neutralizing, one can easily ascertain if a prescription has been executed correctly, by taking from the trial case the lens or lenses which should neutralize those of the prescription if the latter has been accurately filled, and observing whether there is any apparent movement of the objects when these lenses are held in contact and moved before the eye. Of course it is unnecessary to add that there would be no movement if the lenses are accurate.

Caution.—In the case of *deep* spherical lenses, it is often only possible to neutralize the *centres* of the lenses; in which case there would be a slight movement on looking through the edges of them; but this is only so in very strong powers, so that it is not likely to be a source of great trouble to the reader.

It is suggested, for the benefit of those who might find a difficulty in neutralizing deep lenses, to place between the lens you are testing and the one you are neutralizing it with, a paper disc having a central aperture sufficiently large to take in the central part of the lenses, cutting off the periphery. Tissue paper is perhaps the best to use, as it must be remembered that, unless the lenses are in contact, the result will be seriously interfered with. For instance, a convex lens, if removed from the eye, is increased in power, and a concave lens loses in strength; or in other words, *the focal length of a convex lens diminishes by the distance it is removed from the eye;* and conversely, *the focal length of a concave lens increases by the distance it is moved away.*

Therefore, if when neutralizing two lenses, their surfaces do not exactly touch, an error is likely to arise. For sake of example:— a + 10D. and – 10D. placed 5 m/m. apart, are not plane glass. The convex lens being in front, the two lenses combined equal approximately + ·54D.; because a + 10D. lens in this position has a focal length of 100 m/m., *less* the distance separating the two lenses, *i.e.*, 95 m/m. (100 – 5 = 95), which represents a lens of + 10·54D. ($\frac{1000}{95}$).

If the concave had been in front, then the combined lenses would be + ·48 (approx.); since the − 10D. equals, in its present position, a lens having a focal length of 100 m/m., *plus* the distance separating the two lenses (*i.e.*, 105 m/m.) which is − 9·52 about ($\frac{1000}{105}$).

Two lenses, in order to neutralize must be separated by a distance equal to the algebraical addition of their focal lengths; which, when applying to lenses of different kind (*i.e.*, + and −), is equivalent to the *difference* between their focal lengths. *Example*:—a + 5D. must be 100 m/m. in front of a − 10D., to neutralize it; because + 5D. has a focal length of 200 m/m., and since this *decreases* as the distance from the eye increases, it must be advanced 100 m/m., to make the power of the lens equal to + 10D., which has a focal length of 100 m/m. If the − 10D. was in front of the + 5D., it would also have to be separated by a distance of 100 m/m.; since the focal length of a concave lens *increases* by the distance it is advanced. Removing it 100 m/m. would make the focal length twice as long, or its dioptric power half its original strength, viz., − 5D.; or, in the terms of the rule just given, + 5D. = focal length of 200 m/m., and − 10D. = 100 m/m.; the difference being 100 m/m., which gives the amount of separation necessary to effect neutralization. Had we been considering two positive or plus lenses, then their separation would equal the *sum* of their focal lengths. Thus, + 20D. must be separated 4 inches from another lens of 20D. to nullify its effect.

Explanation.—Parallel rays, after passing through the first lens, converge to 2 inches on the other side; now, if the second + 20D. lens is situated 2 inches further away, this point where the rays cross and diverge, is at the focus of the lens; therefore, after refraction, they will emerge parallel. In the same way, + 10D. must be 9 inches from + 8D., for the rays to emerge from the second lens as parallel; that is to say, for the effect of the + 10D. to be neutralized by the +8D.

Before leaving the subject of cylinders, I may as well tell

you that in your researches you will probably read of such things as "cross cylinders," but those who read this work will never have occasion for the use of them, as they will know that, in effect, all sphero-cylindrical lenses are cross cylinders.

In neutralizing prisms, whether they be plano or in combination with a sphere or any cylindrical lens, the best way to adopt is, to read the amount of displacement off a prism chart, as described in the last chapter. To do this, it may be necessary to neutralize the spherical or cylindrical element first, so as to see clearly through the lens; in which case do so. If you are standing at the correct distance for the scale in use, each division the zero line is displaced represents 1^{Δ}. Care must be taken that you are exactly at the requisite distance from your chart; or the reading must be modified, as previously explained. If preferred, the displacement can be neutralized by means of a second prism, held base against apex, the strength being gradually increased, until the zero line of tangent scale is shifted back to its proper position.

The first method is more convenient, particularly where the prism is combined with a sphero-cylinder; as the neutralizing lenses for the dioptric power will be found enough to hold in position, without the addition of a prism.

Prisms, when prescribed, are either used by themselves, or else in combination with a spherical or compound lens; in which case, when the power of the lenses will permit of it, this prismatic element can be best obtained by decentring the glass—that is, by purposely displacing the optical centre a certain distance from the geometrical centre of the lens. This has the advantage of being lighter, and also considerably less costly than grinding the prism. This decentration can be obtained with equal facility in either convex or concave lenses; a given decentration having the same prismatic effect in either case—the only difference is, in the direction of the resulting prism; a convex lens decentred outwards, being equivalent to a prism *base out*, and a concave lens decentred

outwards having the effect of a prism base *in*. Therefore, you decentre a convex lens in the direction you wish to have the base of your prism; while in the case of a concave lens, you must decentre it in the opposite direction to the desired base.

The result of decentring is directly proportional to the dioptric power of the lens; so that, the stronger the glass, the less decentration required to produce a given prismatic effect. In a 1D lens, a prismatic effect of 1^{Δ} is obtained by every centimetre of decentration; therefore, to ascertain the effect of any given decentration, you multiply the dioptric power of the lens by the decentration expressed in centimetres. For example:—A 4D lens decentred 5 m/m., has a prismatic element of 2^{Δ} ($4 \times \cdot 5 = 2$). Then again, a 3D lens decentred 1 c/m., equals a prismatic effect of 3^{Δ} ($3 \times 1 = 3$).

Now, to ascertain the decentration required to produce a given prismatic effect in $^{\Delta}$, it is necessary to divide the dioptric power of the lens into the prism produced. Thus, to obtain 2^{Δ} in a 4D lens, it requires to be decentred 0·5 c/m., or 5 m/m. (4 into 2 = ·5). Or, to produce 3^{Δ} in a 3D lens, it will need to be decentred 1 c/m. (3 into 3 = 1).

If you know the decentration of an unknown lens, together with the prismatic effect this produces; in order to find out the dioptric strength of the lens, you simply divide the prism by the decentration in centimetres. Try this with the last two examples, and you can verify it for yourself.

Decentration, when required, is generally along the horizontal or vertical meridians; that is, a prismatic effect having the base in or out, or else up or down. In spherical lenses, the power in all directions is equal; but when dealing with sphero-cylinders, it is necessary to estimate the strength of the combination in the direction under consideration. For instance, if wishing to decentre $+ 4$ sph. $\bigcirc$ $+ 2$ cyl. ax. 180°, so as to obtain a prism effect of 2^{Δ} base in, it is the horizontal meridian you will be using. As a cylinder has no curvature

along its axis, this combination in the horizontal equals only + 4 (the spherical power); so that, according to the rule given previously, this lens should be decentred ·5 c/m. inwards ($\frac{2}{4}$ = ·5). Now, had it been necessary to decentre the lens vertically, in order to obtain a 2^{Δ} prism base up, then we should have to consider the power both of the sphere and cylinder; because the sphere has its strength distributed all over the glass, and a 2D cyl. with its axis (plane direction) horizontal, has an effect of 2D at right angles to this (*i.e.*, in the vertical). Therefore, the total power vertically, would be 6D; and the decentration would need to be ·33 c/m., or 3·3 m/m. ($\frac{2}{6}$ = ·33).

It is sometimes required to decentre a compound lens in which the axis of the cylinder is oblique; in which case you must calculate the value of the cylinder in the direction of decentration, and add this to the power of the sphere, if any. To ascertain the value of a cylinder when its axis is oblique, in any other meridian, multiply the dioptric strength of the cylinder by the number of degrees at which the axis is set from the direction required, and divide by 90. For example:— + 6D cylinder, ax. 135°. To find value in the horizontal, $\frac{6 \times 45}{90} = \frac{6}{2} =$ 3D. To determine value in the vertical of + 4 cyl. axis 60°, $\frac{4 \times 30}{90} = \frac{4}{3} =$ 1·33D.

So far, we have been considering decentration to produce a prismatic effect in terms of the prism dioptre; but it may be necessary to solve these problems also in terms of degrees of refracting angle (°), or degrees of deviation (°D). The simplest way to do this, and one which avoids the memorizing of more rules, is to reduce either of these to its equivalent value in prism dioptres, as seen from Table on page 47 (since this is based upon a refractive index of 1·52 for spectacle glass); and work out as just explained. The two following examples should make this suggestion clear:—

(1). How much would you decentre a + 4·50D lens, to obtain a prism effect of 5° base out?

Since 1° = ·9$^{\Delta}$, 5° = 4·5$^{\Delta}$; and 4·5 divided into 4·5 gives us 1 c/m. decentration, outward.

(2). What would be the decentration necessary to produce 2°D in a − 7D lens, base in?

1°D = 1·745$^{\Delta}$; 2°D = 3·49$^{\Delta}$. Divide 7 into 3·49, and you get practically ·5 c/m., which is the required decentration outwards to produce the desired effect.

Rules for working out decentration in degrees of refracting angle, are given in Chapter XIV., to illustrate the effect of ill-fitting frames; and that method may be used, instead of the one suggested above, with equal accuracy, if preferred.

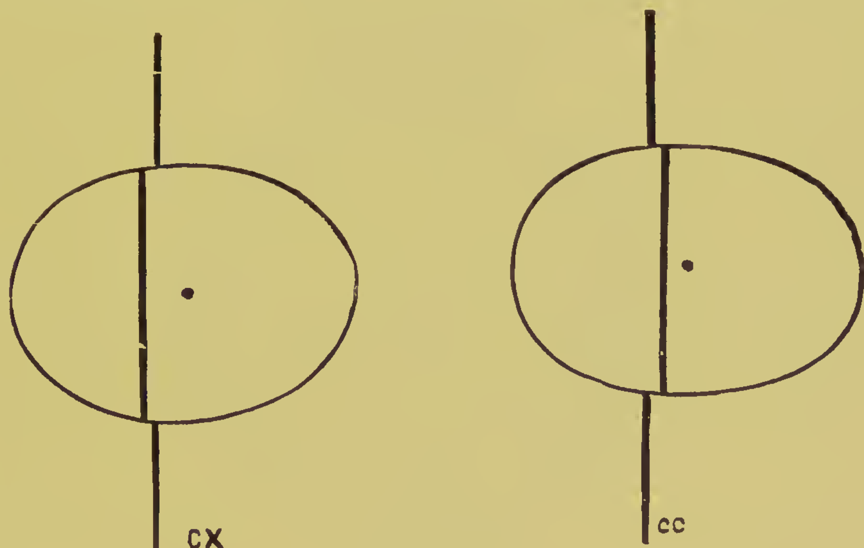


FIG. XXXVII.

The indispensable construction of a good lens (unless a prismatic effect is particularly desirable) is that it is properly centred, as inaccuracy in this important particular would not only cause the unfortunate wearer considerable discomfort, but would also counteract any benefit he might have derived from wearing the glasses, had they been properly coned. The simplest method of locating the position of the optical centre of a lens is, to look through it at a straight line drawn on a card; the line being long enough to be seen through the entire lens, and also above and below it. On looking through the lens at this line, at any part other than the optical centre, it

will not appear continuous with the portions seen above and below the lens. In a convex lens, the part seen through the glass seems deflected from the optical centre; whereas in a

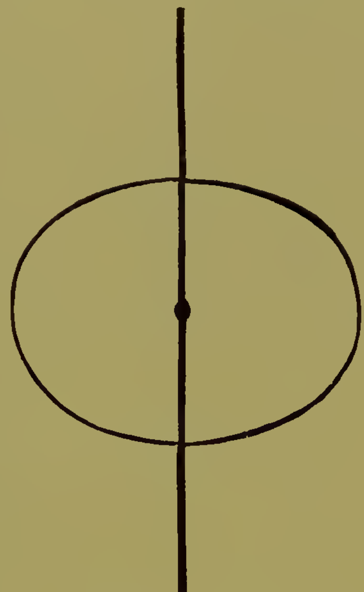


Fig. XXXVIII.

concave lens it would appear to be carried toward the optical centre (see Fig. XXXVII.). When looking through the optical centre, however, the line will appear continuous, both above,

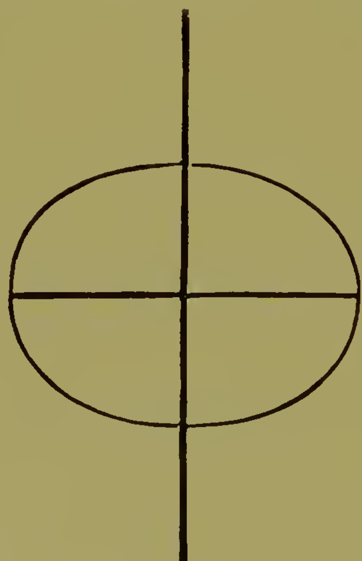


Fig. XXXIX.

through, and below the lens. Therefore you move the lens about until the line appears continuous, as in Fig. XXXVIII.;

when you trace a line on the lens with ink (or a grease pencil, used for marking glass) directly over the one seen through it. Now rotate the lens to right angles to the position it was in, and repeat the process of moving it about until the line is again unbroken; when you draw another line across the face of the lens, directly over the one observed through it. The point of intersection of the two lines represents the position of the optical centre of the lens (see Fig. XXXIX.), the point so called is that at which both opposite surfaces of the lens are parallel; and rays of light traversing a lens and passing

Fig. XL.

through the centre (other than the principal axis), always emerge parallel to their direction on entering.

The optical centres of spheres and cylinders are both found in the same manner; the only little (though important) exception in the case of a cylinder (especially if the axis is oblique), being that you must remember to get the object line to correspond to the axis of the lens, before you can accurately locate the centre.

Before bringing this chapter to a close, we will mention one of the instruments commonly used to measure the strength and kind of lenses. It is called a Spherometer, or Lens

Measurer, and is very useful as a rapid method of ascertaining the strength of lenses, although it should not be solely relied upon to get accurate results, but should always be verified with the lenses from the trial case by taking therefrom the powers indicated by the instrument, and seeing if they are correct. For the benefit of those of my readers who may not have the time to spare to run through the procedure of neutralizing with lenses, and to whom a Lens Measurer would consequently be invaluable, I describe below the method of using it.

To enable the reader to gather an idea of what this little instrument is like, I give a full sized illustration of it (page 65). As seen in the illustration, there are three points at the top of the instrument; the two outer ones being fixed, but the centre one is moveable. To measure a lens, press it firmly upon these three points, which will cause the centre one to be depressed and act upon the index finger, rotating it, and making it point to a figure on the dial, which will indicate in dioptres the refraction of this surface of the lens. If the finger points to the left of zero, it is convex; if to the right of 0, it is concave. Now measure in the same way the other side of the lens, and if both surfaces are convex, or both concave, the numbers are added together. For example: if one side registers + 1, and the other also + 1, the lens is + 2D; if one surface is – 1·50, and the opposite is – 2, the lens equals – 3·50D. Suppose that one side is convex and the other concave (as in the case of periscopic lenses), one side is deducted from the other. For instance: if one surface registered + 2·50, and the other – 1, the lens would be a periscopic convex of 1·50D. Should one side be – 3 and the other + 1, the lens is a periscopic concave of – 2D. If, on rotating the lens on the three projections, the index figure remains pointing to the same number in all meridians, it is a spherical lens. If, however, there should be a difference in the position of the pointer, it proves the lens to be a cylinder. In order to ascertain the axis, we rotate the lens until the finger points to zero, which shows that this direction

has no refraction (or is plane glass), and indicates the position of the axis. Then turn the lens at right angles to this meridian, or to the place where the pointer swings farthest from 0, when the power of the cylinder is read off the scale. In compound lenses each surface should be measured separately.

The foregoing instructions will show how to determine the spherical and cylindrical powers. Write down the measurement of each side separately, as follows: If one surface measures + 3 sphere, and the other + 1·50 cylinder, axis horizontal (180°), you would write: "+ 3 sph. ⊃ + 1·50 cyl. ax. H."

If you are measuring a plano lens, each surface will register 0, and on rotating the lens there will be no movement of the index finger.

Although the above instructions seem simple enough, it should be borne in mind that it is always better to look upon the Spherometer as a handy aid when one is busy than to be dependent upon it from lack of knowledge of neutralizing with lenses; and, therefore, all should prefer the latter method, and adopt it generally in preference to any instrument.

As a matter of fact, the Spherometer here described must of necessity be only an approximate guide to the actual powers of lenses, as no consideration is given to the lens thickness, and the instrument is "set" to a given refractive index; whereas the lenses one may be called upon to test will probably vary—although, as far as we are concerned with lenses as visual aids, the powers are too weak to be seriously affected by these two factors.

If the measure is scaled for an index of refraction of 1·52, and indicates a lens as being 20D, when its refractive index is really 1·6, the actual power (thickness being neglected) can be reckoned by multiplying the dioptres registered by the actual index of refraction of this lens, and dividing by 1·52 (for which the Spherometer is set).

Thus, $\frac{20 \times 1\cdot6}{1\cdot52} = 21\cdot05\text{D}$.

CHAPTER IV.

ACUITY OF VISION.

Although the "acuity of vision" and the refraction of an eye are totally different, yet they are frequently confounded; and for this reason, the refractionist should clearly comprehend the meanings of both these terms. Acuity of vision signifies the formation of accurate impressions on the Retina of the images of external objects, and, furthermore, the transmission of these images, by the nerve-system of the eye, to the brain, so as to produce distinct sight. On the other hand, the refraction of the eye is the function of the refractive media, and has reference to the action of this body on the rays of light that pass through it. The refraction may be perfectly normal, and the rays from an object may be focussed exactly on the Retina by the dioptric apparatus of the eye; and still the person may not be able to see, if the nervous system of the eye fails to perform its function, and the image formed on the sensitive coat of the eye is not conveyed to the brain by the Optic nerve.

Then, again, the acuity of vision may be perfect, in spite of an abnormal refraction, if it be properly corrected by lenses or by other means, as in Hypermetropia by the accommodation; therefore it is no criterion of a normal refraction that a patient can read the distant charts distinctly.

The principal object in testing the sight is, to bring the visual acuity up to normal should it be below it; and this is attained, in the majority of cases, by correcting the refractive condition of the eye. Thus it is obvious that, by increasing

the acuity of a patient's vision, you at the same time correct the refraction of the eye. The first step, then, in the procedure of testing is to ascertain the acuteness of vision without any lenses; for the purpose of comparing it with the vision of the patient after having found the necessary correction. This should be done with each eye separately; as otherwise you would not know whether the patient was using one or both of his eyes.

Fig. XLI.

In order to measure the acuteness of vision, it is necessary to have some standard test for comparison. With this object in view, Distance Test Cards have been made, on which are printed various letters of the alphabet. Since it has been proved that objects, in order to be seen as two, must be separated by an angle of one minute, the smallest retinal image

which can be seen at the yellow spot (macula lutea) must correspond to an angle of this dimension. The letters of the test types are drawn in such a manner that, when they are situated at the proper distance from the eye, each part of them is separated from the other by an interval equalling not less than an angle of one minute at the nodal point; while the entire letter subtends an angle of five minutes. (Test types so made are after Professor Snellen, and are those universally used).

The nodal point of the eye is situated just in front of the posterior surface of the Crystalline Lens, and is the point where all rays of light that enter the eye intersect.

By referring to the test types illustrated here (Fig. XLI.), you will observe that the letters gradually diminish in size, from the top to the bottom of the card, and that over each line of letters are certain figures; these represent the distance at which an eye possessing the average acuteness of vision should clearly discern the letters over which they are written. The different distances in this chart are indicated, for convenience, in both feet and metres; but we shall in future use the metric system in preference to feet.

As before explained, all the letters on the types are so constructed that at their requisite distance from the eye they subtend an angle of five minutes.

The letter G, for example, in Fig. XLII., subtends an angle of five minutes at the nodal point, at the distance of six metres, or twenty feet. The letter E subtends an angle of five minutes at twelve metres distance, and D at twenty-four metres also forms an angle of five minutes at the nodal point of the Crystalline Lens. It is easily understood, then, that it is of no matter to us whether the patient recognises the G at six metres, or the D at twenty-four metres, as each letter at its respective distance subtends the proper angle at the nodal point. So you see it is unnecessary to plaçe the card at such an inconvenient distance as twenty-four metres or more; but instead, you may

place it at six metres, or 4·5 if you have not six metres length in your consulting-room; or even at three metres if necessary. If the card is placed at six metres, the normal or standard eye should read easily the line marked six metres or twenty feet, or if the card is placed at three metres from the patient, the three-metre or ten-feet line should be seen by the normal eye, provided there is a good light upon the card. Now this is an important point—the chart should be so placed that there is a good light upon it; and this light must be evenly distributed, so that each letter is equally well illuminated. If daylight is the source of illumination, the card is best placed facing a window; and the patient should sit with his back to the window. If

FIG. XLII.

artificial light is used, the best is an Argand burner or electric light, which must be placed in such a position as to throw a good illumination on the card, and must not be seen by the patient; or at least the rays should not fall directly upon his eyes, as this would prevent the patient seeing distinctly. A good reflector is perhaps the most useful means of hiding the light from the patient's eyes. I prefer artificial light myself, as the amount of illumination is always the same, and if a patient must be tested twice (which is frequently the case), then it is done under the same conditions both times—whereas, if one tests by daylight, one must necessarily be dependent upon the weather; and everyone knows what *that* means, in this uncertain climate. However, the essential points are that you obtain a good light, and that it is evenly distributed over the chart.

On looking again at our illustration, you will notice that there are lines of letters ranging down from those which should be seen at forty-five metres, to those which the perfect eye ought to read at three metres. Of course, there are many people who have less than the normal acuity of vision, who would possibly see at six metres only the lines that should be

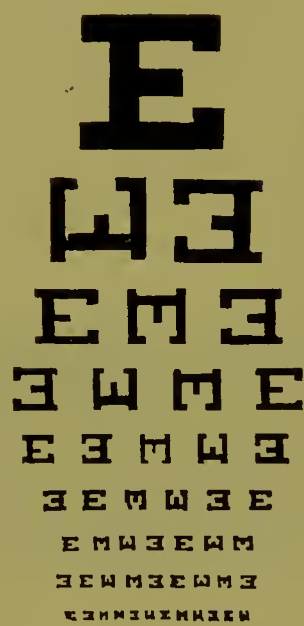


Fig. XLIII.

read at twelve metres; or perhaps only those which ought to be seen at forty-five metres—and there are some patients who cannot see even these. In order to facilitate the recording of our patient's vision both before and after the sight is corrected, the acuity of vision is expressed by a fraction, the numerator of which represents in metres (or feet, if the student prefers recording it thus) the distance at which the types are situated from the patient; and the denominator the distance at which the letters should be read by a normal or standard eye. Suppose a person can see at six metres the six-metre line, his vision is recorded thus: "$V. = \frac{6}{6}$"; or if in feet, "$\frac{20}{20}$". If, however, the patient can only discern the twelve-metre line at this distance, his vision equals $\frac{6}{12}$. The meaning, then, of $\frac{6}{60}$, $\frac{6}{30}$, $\frac{6}{18}$, $\frac{6}{9}$, etc., should be clear. Occasionally, a person reads

the distance type better than normally; for instance, at six metres away he sees what the normal eye should read at three metres; his vision is recorded thus: "V. = $\frac{6}{3}$".

In addition to the distance test charts just mentioned, there are numerous cards printed for testing the near vision, for reading, sewing, etc. The ones preferred by the author are those of Jaeger, as his letters are of the ordinary shape; whereas the others are block letters, and not such as one would be required to read.

The letters are of various sized types, the smallest being No. 1; and are marked on top with the distance at which they should be seen by the normal eye possessing good sight. As will be fully explained later on, you must never rely on these cards to ascertain your patient's refractive condition; but always test your patient's sight at a distance first—because for looking at near objects the accommodation must be brought into play, and it consequently either minimises or magnifies the apparent amount of the defect, if any.

Astigmatic test types, such as Pray's letters, the clock face, sunrise, etc., will be thoroughly explained in the chapter devoted to testing. There are no special reading cards for use with astigmatic patients; the ordinary ones being all that is required, after having obtained the cylindrical correction at a distance.

In cases of children and illiterates, I find that, instead of using the ordinary letter types just described, it is better to use charts on which are printed a series of E's varying in size, according to Snellen's dimensions, from sixty metres (two hundred feet) to three metres (ten feet), and arranged with the arms in various directions, so that the position of the letter can be pointed out by the patient. This test can be made still more attractive to little ones, if a model E is given them in their hands, to be held in the position of the E to which the refractionist points on the chart; they thus look upon the test in the nature of a game, and entering into the spirit of it, lose

the customary shyness they would otherwise have with strangers. It is obvious that this chart simplifies the testing of children's eyesight materially; as most children, even if they know the alphabet, would through nervousness, hesitate if asked to read out the letters, with which some are not too familiar.

Experience has shown that this is preferable to the "dot" chart; as although the latter is excellent for illiterates, there is a difficulty with children, owing to the want of concentration, in accurately counting the dots; particularly in the smaller sizes, where they are more numerous.

CHAPTER V.

EMMETROPIA AND AMETROPIA.

THE Emmetropic is the natural, or standard eye, and measures about nine-tenths of an inch antero-posteriorly (*i.e.*, from the front to the back); or, if you would rather have it in fractions of a metre, 22·824 millimetres. It is that condition when the refractive media[1] are sufficiently convex to focus exactly on the Retina parallel rays (or those coming from distant objects), without any effort whatever on the part of the accommodation; and conversely, rays proceeding from the Retina of the standard or normal eye would emerge parallel. Or, to express it differently, the normal eye is one in which the Retina is situated exactly at the focus of its dioptric apparatus.

From these definitions one would imagine that an emmetropic eye would see perfectly; and this is correct, provided that the eye is healthy. An eye may be emmetropic, and still have impaired vision; for it may be diseased, in which case no lenses will be found that will materially improve the sight.

An emmetropic eye, then, would be at rest when regarding distant objects; that is, the "Refractive Media" are capable, without the assistance of the accommodation, of bringing the rays of light to a focus distinctly and clearly on the Retina; so that the standard or normal eye can see distinctly at a distance, when in a static or restful condition. When regarding near objects, however, the rays emanating from them being divergent, and the dioptric system of the eye when at rest

[1] The "Refractive Media" consist of the Cornea, Aqueous Humour, Crystalline Lens and Vitreous Humour.

being only adapted for parallel rays, it is not strong enough to focus these rays on the Retina; and indistinct vision would result, were it not for the mechanism of the accommodation, by which the eye is capable of adjusting its refractive apparatus to this new condition.

In order to bring about this accommodation, the brain sends forth the stimulus to the Ciliary muscle, and it contracts; and by so doing it lessens the pressure exerted on the lens by the suspensory ligament (as explained in a preceding chapter). The Crystalline Lens bulges forward, becoming more convex;

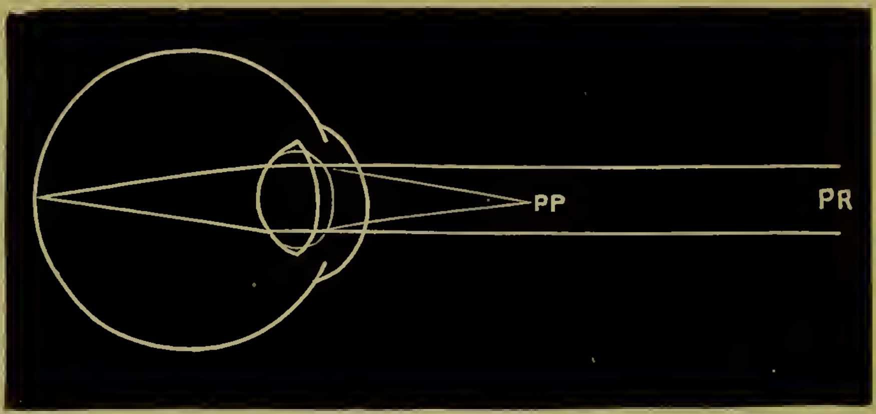


Fig. XLIV.

and is thus enabled to focus on the Retina divergent rays, as well as those coming from a distance (see Fig. XLIV.)

It is obvious, therefore, that Nature intends that the muscle of accommodation shall be used only for regarding near objects; and that when the eye is looking at a distance it should be at rest. When this is the case, the eye is said to be normal; and such a condition is called Emmetropia.

The refraction of the eye when in a state of rest is termed static; dynamic refraction is when the accommodation is brought into play.

The accommodation, then, is for enabling an individual to see objects close by, and, like all our other faculties, cannot last for ever, but must sooner or later feel the effects of constant use; so even the little muscle responsible for the changeable

refraction of the eye, which has worked involuntarily for so long, is at last weakened, and is unable to perform its function without some slight assistance. The greatest amount of accommodation that an eye can exert in looking at near objects is termed the "amplitude of accommodation," and represents in dioptres the person's near point (punctum proximum); that is, the closest distance from the eyes that an individual can read the smallest type on the reading card. This is convertible into centimetres by dividing the dioptres of accommodation into 100; or you can reduce it to inches by dividing 40 by the number of dioptres of accommodation the person possesses.

The *amplitude* of accommodation is the greatest effort that the eye is capable of making, and may be either of the three following kinds: Binocular, Relative, and Absolute.

1. Binocular is the term given to the greatest amount of accommodation that can be exerted by the two eyes when allowed to converge.
2. Relative: the full extent of accommodation that can be brought into play by both eyes together, for any given convergence of the visual axes; and
3. Absolute is the greatest effort which each eye can exert separately.

However, when in future we speak of measuring the accommodation, we refer to Binocular; that is, when the eyes are allowed to converge as much as necessary in order to read the test types, or the book in use.

It is seen that, under natural conditions, accommodation is a function of "near vision," and convergence must be considered (within certain limits) its inseparable companion in binocular vision (that of both eyes together); as obviously, the visual axes of the two eyes need to be simultaneously directed to the object under observation, so that the two images are formed on corresponding parts of the retinæ, in order that it

may be seen singly. Unless this is so, Diplopia, or double vision, results. This directing of the visual axes to a point within infinity is the function of convergence; and it is brought about by the action of the internal recti muscles, which receive their supply of nervous energy from the same source as the

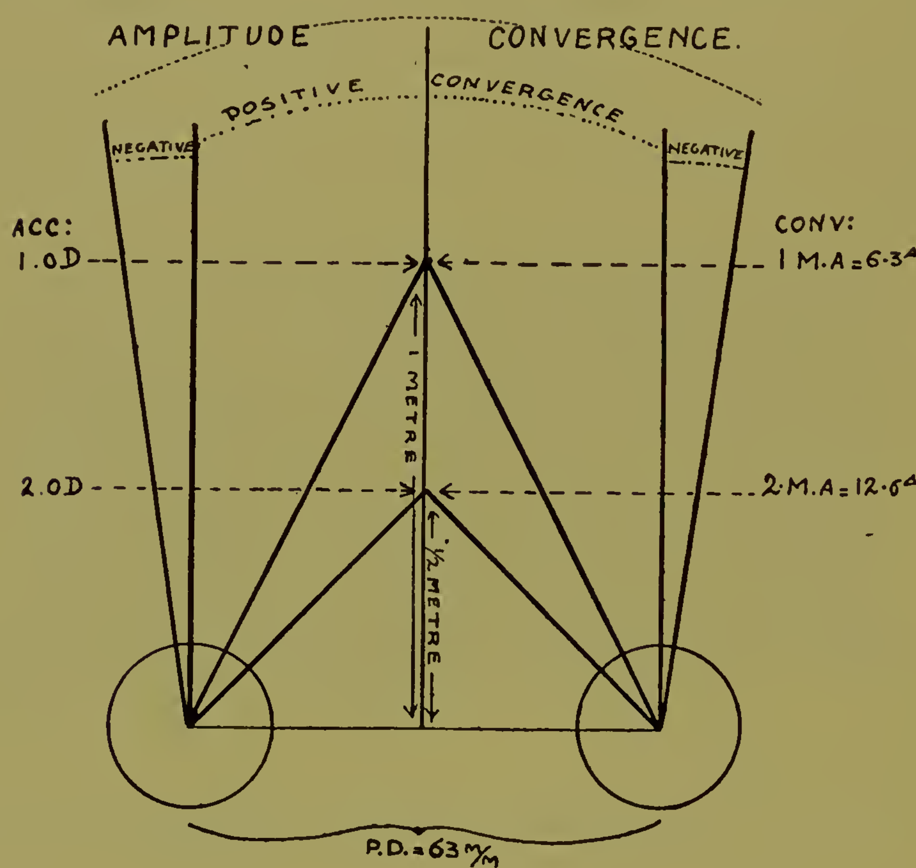


FIG. XLV.

On the left is shown the accommodation required in *each* eye, and on the right the convergence in metre angles and prism-dioptres for *both*, when the eyes are adjusted for the distances indicated.

Ciliary muscle, that is, the third, or motor oculi nerve. Thus, these functions of accommodation and convergence are connected by association of habit and supply.

Accommodative effort, which results in an increased refraction of the dioptric system of the eye, is expressed numerically, the amplitude being spoken of as so many dioptres; but convergence, being an angular deviation, is expressed in angular measurements, the unit of convergence being one

metre angle. Suppose the two eyes to be directed to infinity, the visual axes will be approximately parallel; but when the eyes are turned toward a point one metre distant, the visual axes are seen to form a certain angle (see Fig. XLV.), and this is known as a metre angle, upon which is based the measurement of the convergence.

If the eyes are directed to a point just one-half this distance, the angle is twice as great, and is called two metre angles (2 M.A.); and conversely, when the eyes are fixing an object at four metres away, the convergence would be equal to 0·25 M.A.—just one quarter the effort necessary when compared with that for looking at a distance of one metre. Therefore, the convergence of the eyes regarding an object at a given distance within infinity, can be converted into M.A. in the same way as the amplitude of accommodation is determined by the near point; that is, by dividing the distance, when in centimetres, into 100, and when in inches, into 40, the quotient will be in terms of M.A.

When fixing any point within infinity, the convergence required is termed *positive;* when looking beyond infinity (that is, if the visual axes diverge), it is called *negative convergence*, the positive added to the negative convergence giving the amplitude. (See also Fig. XLV.) This can be measured by ascertaining the strongest pair of prisms, bases out, and the strongest with their bases in, that a person can overcome when fixing an object at a distance of 20 feet or more, and still see singly. Thus, the power of the interni, plus that of the externi, equals the amplitude of convergence.

Now, whereas the accommodation is a fixed effort, it is obvious from accompanying illustration, that the amount of convergence necessarily depends upon the distance between the eyes; therefore the metre angle is not a constant quantity, but varies with the inter-pupillary distance. Since a 1^{Δ} prism produces a displacement of one centimetre at a distance of one metre, the value of 1 M.A. of convergence, in terms of prism

dioptres, equals the inter-pupillary distance expressed in centimetres. Thus, if the inter-pupillary distance is 63 m/m., 1 M.A. = $6{\cdot}3^{\Delta}$; and from this, the convergence at any distance may be calculated in prism measurements.

Example: What is the convergence of the eyes, in terms of $^{\Delta}$, when looking at a point 33 c/m. away; the inter-pupillary distance being 58 m/m.?

$$1 \text{ M.A.} = 5{\cdot}8^{\Delta} \therefore 3 \text{ M.A.} \left(\tfrac{100}{33} = 3\right) = 17{\cdot}4^{\Delta}.$$

Of course, such convergence is divided equally between both eyes; so the amount in each eye is $8{\cdot}7^{\Delta}$.

The accommodation, so to speak, is an individual effort, and the full amount is exerted by each eye; but convergence is essentially binocular, and consequently shared between them both—so that the ratio of accommodation to convergence is established as being practically 2 to 1. Thus, in regarding an object 50 c/m. away, there is an accommodation of 2D involved in each eye, to overcome the divergence of the rays from this distance; but since the two eyes turn towards this point (which represents 2 M.A.), the actual deviation (or convergence) for each is only 1 M.A.

The intimate connection between these two functions, as demonstrated above, is important to maintain; and it is when this natural harmony between accommodation and convergence is disturbed by uncorrected errors of refraction that trouble occurs. (See Chapters VI., VII., and XI.)

In youth the accommodation is most vigorous, and it gradually becomes less so with age. At ten years of age the amplitude of accommodation begins to diminish, and the power gradually lessens until, at seventy years, there is none left, and the near point (PP) has receded so far that it, and the far point merge. The far point is called the punctum remotum, and is the farthest distance at which a person can see; in Emmetropia it is situated at infinity (abbreviated ∞).

The following table shows the average Amplitude of

Accommodation and Near Point of an emmetropic eye, from ten to seventy years of age :—

Age.	Amplitude of Accommodation.	Near point. Inches.	Centimetres.
10	14D.	$2\frac{3}{4}$	7
15	12	$3\frac{1}{4}$	8
20	10	4	10
25	8·5	$4\frac{3}{4}$	12
30	7·0	$5\frac{1}{2}$	14
35	6·0	$6\frac{1}{2}$	16
40	4·5	9	22
45	3·5	11	27
50	2·5	16	40
55	1·5	26	65
60	1·0	40	100
65	0·5	80	200
70	0	∞	∞

The reader must not presume that, because an emmetrope (*i.e.*, a person with emmetropic eyes) of forty can exert 4·5D. of accommodation, he is able to read at nine inches from the eyes for any length of time. It must be well borne in mind that to see at nine inches the person has to exert the maximum amount of his accommodation, and that no muscle can maintain its full power for any considerable period. It is a recognised fact that the average amount of accommodation that an emmetrope can exert for any length of time is two-thirds of the whole, after about middle age; in youth, of course, more than this may be exerted without any ill effects. So that at forty years a person would be able, without suffering any inconvenience, to use 3D. of accommodation (*i.e.*, two-thirds of 4·5D.), and this would enable him to read comfortably at thirty-three centimetres, which is the usual reading distance. It is after this age, when the available accommodation is insufficient for the person to

read at this distance, that the need of glasses for reading is first manifested in the emmetropic eye. So it is seen that up to this age a healthy emmetropic eye does not require glasses, but after forty Presbyopia, or old sight, sets in, and glasses must be given for reading.

Presbyopia is mentioned under the heading of "Emmetropia" for the reason that it is not an error of refraction, but merely an ordinary senile change, which occurs in every eye without exception. It may be expected as surely as one's hair turns grey with age; it is impossible to postpone this failing of the Ciliary muscle to perform its work, and it occurs in all eyes. Errors of refraction may hasten it, or on the other hand may disguise it; but the Presbyopia is there, only it is not noticeable because the increased refractive condition of the eye counterbalances or neutralizes this lessening of power of the refractive media which is due to the weakening of the Ciliary muscle and loss of elasticity of the Crystalline Lens.

So, then, for this reason, some people may postpone the wearing of spectacles; but others, who do so for fastidious reasons, are either ignorant or unwise. (This condition will be mentioned in detail in the chapter on Presbyopia.)

Ametropia is any departure from that condition just described as Emmetropia, and it signifies that "the eye is out of measure." An eye may be called ametropic, or abnormal, when parallel rays of light are focussed either behind or in front of the Retina; or when the muscle of accommodation has to come into play, so as to make the Crystalline Lens more convex in order to focus parallel rays on the Retina, and thus preserve distinct vision. In other words, the eye is ametropic when the refractive media are not strong enough to focus parallel rays on the Retina, so that they reach it before coming to a focus, and thus form on the Retina a diffuse or a blurred image, instead of a perfectly defined one. This condition—namely, Hypermetropia, or "far sight"—constitutes the most prevalent of all errors of refraction, and one which is the cause

of many so-called diseases, such as inflammation of the lids (Blepharitis), or of the conjunctiva or mucous membrane, and others too numerous to mention here.

Or, Ametropia may exist when the refractive media are too strong, and focus the rays of light within the Vitreous Humour (*i.e.*, in front of the Retina), where they cross, and reach the Retina confusedly; and the image of the object observed is therefore not clearly defined. This state of affairs constitutes Myopia, or "near sight," which is, in all respects, the exact opposite of Hypermetropia.

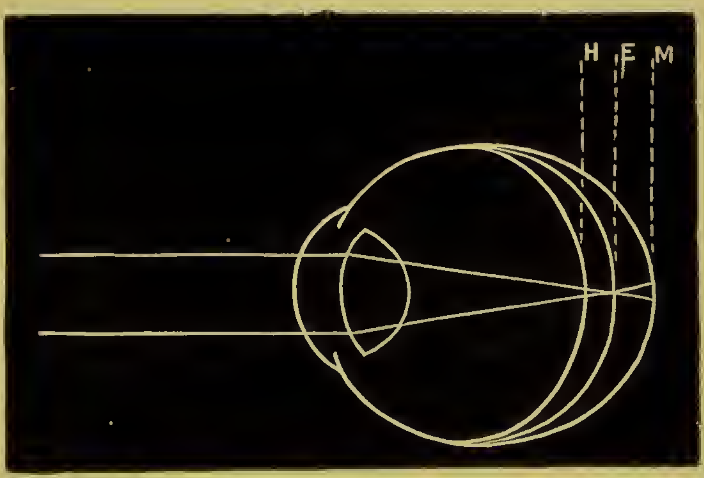


FIG. XLVI.

Ametropia, then, results when the sensitive coat of the eye is not in the focus of the refractive media; either through fault in the media themselves, or in the shape of the ball. It is of two principal forms, Hypermetropia and Myopia. The accompanying diagram shows very clearly the position of the focus of parallel rays in an emmetropic eye, compared with that of Hypermetropia and Myopia.

In an emmetropic eye, the rays are seen to focus exactly on the Retina (see E, Fig. XLVI.); but in the case of the hypermetropic eye, whose axis is shorter than that of the normal one, the rays reach the Retina before arriving at their focus. In the myopic eye you have exactly the reverse condition; that is, the rays of light attain their focus before

reaching the Retina, because the eye is lengthened abnormally, so that the Retina is situated beyond the focus of the refractive media (see H and M, Fig. XLVI.).

We have seen that the size of an image decreases with its distance from the optical centre of a lens; therefore, by the same law, the retinal image is larger in Myopia, since the nodal point is further from the Retina than in Emmetropia. And in Hypermetropia the retinal image is smaller, owing to the nodal point being closer to the Retina. The influence which Hypermetropia and Myopia have upon the size of the retinal image, can be calculated as explained on page 35; bearing in mind, however, that 1 m/m. alteration in the axial length of the globe equals a 3-dioptre error.

The retinal image of an object 8·5 m/m. high, situated six metres away, would be ·021 m/m. in an emmetropic eye.

Had the eye been myopic 15D, this would have been ·028 m/m.; as follows:—

Myopia of 15D makes the distance of the nodal point from the retina, approximately 20 m/m., instead of 15 m/m.; so that we get, $\frac{8{\cdot}5 \times 20}{6000} = \frac{8{\cdot}5}{300} = {\cdot}028$ m/m.

In Hypermetropia, the distance of the nodal point would be reckoned so much less (3 dioptres representing 1 m/m.); and consequently, the retinal image would work out smaller.

It is on account of this small image that Hypermetropes and Hypermetropic Astigmats bring the object close to the eyes; as by increasing the visual angle in this way, a larger retinal picture is obtained.

Astigmatism is another common departure from the normal conditions. It is caused by an elongation or shortening of one or more of the meridians of the Cornea, and is a combination of Emmetropia and some form of Ametropia, or of two kinds of abnormal vision (Hypermetropia and Myopia) in the *same* eye; so that it is incumbent upon us to fully understand these two defects before undertaking to master Astigmatism.

The following chapters will be given entirely to the consideration of the causes and corrections of these various forms of Ametropia. Each one will be discussed separately and exhaustively; so that the reader, after finishing one variety, will be in a position to test and prescribe the necessary lenses in such a case, before going forward to study another of the anomalies of refraction.

CHAPTER VI

HYPERMETROPIA.

Hypermetropia, or Hyperopia, means "long sight," and is very much more common than Myopia; although the prevailing idea appears to be exactly the opposite. Hypermetropia, although more prevalent, is not so noticeable to the individual, possibly, as Myopia, or short sight; for the reason that, if it is of moderate or slight amount, the patient is able to overcome his defect, unknown to himself, sufficiently to enable him to see distant objects clearly (or even near objects, if the patient is young, and his defect of slight degree), by involuntarily exercising his accommodation. Consequently he is not inconvenienced by his defect; in fact, the hypermetrope is not aware of any defect until, from sheer exhaustion of the Ciliary muscle, he is obliged to visit the refractionist—whereas a myopic person has no means in his power by which he can disguise his condition.

We have seen that in Emmetropia, rays of light from distant objects are focussed on the Retina without any effort on the part of the accommodation, because the static (or restful) refraction of such an eye is just sufficient to accomplish this; whereas in Hyperopia, this being a condition in which the eyeball is insufficient in length antero-posteriorly (it being under nine-tenths of an inch, or 22·824 millimetres in length), the rays do not meet (or come to a focus) before they reach the Retina; and if it were practicable, they would be brought to a focus behind it. This, however, cannot occur; as it is

impossible for the rays to go through the Choroid and Sclerotic —they consequently meet the Retina in a confused state, before having come to a focus, and indistinct vision is the result. A little thought on the reader's part will remind him that this is the same condition of affairs as if an emmetropic eye were looking at near objects. The cause, of course, is different—the former being due to an abnormally short eyeball, and the latter to the divergence of the rays entering the eye —but the result is the same. That is to say, the rays would be focussed behind the Retina, if possible; and in both cases the accommodation must be brought into play in order to bring the rays of light to a shorter focus, and thus on to the Retina. Consequently the hypermetrope (a person who has Hypermetropia), in order to focus parallel rays on the Retina, must overcome his defect by using a corresponding amount of accommodation. Thus it is obvious that a hypermetrope can only see well at a distance by the sacrifice of nervous energy, induced by the constant use of his accommodation; when an emmetropic eye would have been at rest.

In looking at near objects, the "far-sighted" eye would require to bring into use a still greater amount of accommodation; because the rays are divergent, and therefore would require more convexity to converge them to a focus on the Retina than parallel rays; and the closer the hypermetrope brings the object to his eyes, the greater the strain forced upon the Ciliary muscle. Therefore, when a hypermetropic person wishes to read he has a tendency to hold his book farther away from the eyes than a person with normal vision; so as to give his Ciliary muscle as little extra work to do as possible. The usual reading distance is thirty-three centimetres (thirteen inches) from the eyes; and if a person holds his work further away than this, it is safe to assume that he is hypermetropic, if under forty years of age—as if the patient is older than this, the condition might be Presbyopia. Thus a hypermetropic eye is never at rest; because it must necessarily use its

accommodation constantly in order to preserve good vision, with the exception of when the eyes are closed momentarily or in sleep.

Hypermetropia is caused either by:—

1. A shortening of the eyeball antero-posteriorly (or from before backward).
2. A diminution of the index of refraction of the Aqueous Humour, Crystalline Lens, or Vitreous Humour.
3. Absence of the Crystalline Lens (Aphakia).

The usual cause, however, is the shortening of the eyeball. (The third cause, Aphakia, is a separate form of Ametropia, which we will discuss fully in a later chapter). It is immaterial to you which of the above is the cause of the defect, as the correction is the same, and exactly the same kind of lens is required, whether it is a diminution of the refractive media or insufficient length of the eyeball which causes the parallel rays to be focussed behind the Retina instead of on it.

Hypermetropia is more or less congenital; at birth the eyes as well as the rest of the body, being naturally undeveloped, and they do not reach their normal size until between five and six years of age—and it is when this development is in some way retarded that the condition known as Hypermetropia presents itself. This defect, again in contradistinction to Myopia (the tendency of which is to increase), cannot get worse; as the eye, when once of a certain size, cannot become smaller unless in a diseased condition. The reason why the glasses for Hypermetropia have sometimes to be increased in power will be given shortly.

Hypermetropia may be classified as of five different kinds:—

1. Facultative Hypermetropia is when a patient can see the distance test types as well with as without convex lenses. This is found usually in young people, when the accommodation is vigorous.

2. Relative Hypermetropia is when a person can accommodate to a near point by converging to a point still nearer; that is, by squinting inward; and is found generally in middle-aged people. (This condition will be mentioned again, under the heading of Strabismus).

3. Absolute is when the patient's vision is impaired, both near and at a distance. This condition is met with more in elderly people.

4. Latent Hypermetropia is that which is hidden by the accommodation.

5. Manifest: that which is not hidden by the accommodation.

Naturally, one would expect to find the Latent variety of Hypermetropia in young people, as then the accommodation is so strong, that without inconvenience to the individual, the Hypermetropia can be overcome; but in elderly patients, the Ciliary muscle being naturally deteriorated, it would be unable to disguise the defect. Then it is obvious that Latent Hypermetropia develops into manifest as the patient becomes older; and therefore a hypermetrope will require his glasses to be changed for stronger ones at intervals as he advances in years. It should be perfectly understood that these stronger glasses are not given because the hypermetropia has become worse; but merely to correct a part of the original defect which was hitherto concealed. Since there is the tendency to overcome the amount of the error in Hypermetropia, by involuntarily exerting the Ciliary muscle, one should always suspect a certain amount of the defect to be hidden, and must allow for it by giving the strongest possible lens that the patient can tolerate and at the same time see well. Or if the patient is young, even should he be unable to see perfectly with your correction at first, let him persevere in wearing them, and shortly the eye will become accustomed to the changed circumstances, and soon be able to see well with the glasses. But it will be necessary to impress upon your patient that he must persevere, and

should he have any great discomfort with his eyes, return to you. Otherwise he might call upon a "charlatan," who, in all probability, would supply him with a weaker glass and say that "Whoever supplied you with these glasses has made a mistake," or something to that effect; and you would in consequence lose a patient, to his detriment as well as your own —while on the other hand, if you had only cautioned him, this might have been avoided. This is the reason why one frequently hears from a patient that he went to such-and-such an oculist, but was not suited correctly, as the glasses prescribed made the vision all blurred. You can always take assertions of this kind *cum grano salis;* and you may rest assured that a professional man, who has spent years in acquiring his knowledge, in the event of over-correcting a defect, would have some ulterior object in doing so.

The Hypermetropic eye is adapted for *convergent* rays; and since all rays in nature are *divergent*—with the exception of those which come from a distance of six metres (twenty feet) or more, when they are so little divergent that for practical purposes they are considered as being parallel—the Hypermetropic eye is adapted for non-existent rays. Therefore, in order to enable the eye to focus clearly (the accommodation being at rest) rays of light on the Retina, they must be made convergent before entering the eye. And as parallel rays are, on passing through a convex lens, made convergent, this is the kind of lens one would use for the correction of this defect.

The hypermetropic eye never being at rest (that is, the Ciliary muscle being brought into play, both for looking at near and distant objects), and the accommodation being only intended for use for reading purposes, it is necessary to place in front of the eye such a convex lens as will focus parallel rays on the Retina, and thereby do away with the necessity of using the muscle of accommodation for looking at distant objects. The correction, then, for Hypermetropia is the strongest convex lens that gives normal vision or the best results.

(When I use the word "correction," I always mean for a distance, unless otherwise mentioned).

In testing for any kind of Ametropia, you always begin by placing a weak convex lens (say a + 1D.) in front of the eye, because only a Hypermetropic person will see as well with a convex lens as without it, for distance; that is to say, in any other condition (say Emmetropia or Myopia), vision will be made *worse* for distance by placing a weak plus lens in front of the eye; whereas, if the eye be "far-sighted," it will make the vision either better or *no worse.* This fact gives us the following rule, which the reader should commit to memory:—

It does not follow, if a person sees as well with a concave lens as with the naked eye, for distance, that he requires it. But if he sees as well with a convex lens as with the naked eye, for distance, he does require it.

A concave lens is accepted by an emmetropic or hypermetropic eye, as the divergence of the rays produced by this lens is overcome by a corresponding effort of accommodation, which enables the eye to maintain the focus upon the retina; but under no circumstances must such a lens be prescribed. On the other hand, a convex lens, unless the eye is "far-sighted," must reduce the visual acuity at a distance, because it adds to the refracting power of the eye, bringing the focus of the rays before the retina; and since there is no mechanism by which the eye can adapt its refractive power to meet this excessive convergence of the rays and focus them on the retina, the clearness of vision suffers.

Bear in mind, therefore, that if a convex lens makes your patient's vision better, or no worse, he must be Hypermetropic. The fact that a person sees $\frac{6}{6}$, is not by any means a proof that he is Emmetropic—he may be a Hypermetrope using his accommodation, and you ascertain which it is by finding out whether the patient rejects the weak convex lens. If he does, it is Emmetropia; but if he does not see worse through the lens, it is a case of Hypermetropia, where the patient's

accommodation is sufficiently strong to overcome the defect. In facultative Hypermetropia, when viewing distant objects, the accommodation is used to overcome the defect, and so makes vision equal $\frac{6}{6}$. As convex lenses are held before such an eye, the accommodative effort is proportionately reduced, and therefore vision is still $\frac{6}{6}$, until the full error is represented by the plus glass outside the eye; beyond which power vision will be impaired, owing to the focus being brought before the retina, as in Myopia.

It will therefore be quite safe, in testing with convex lenses, to increase their strength until vision begins to blur.

The following three rules should always be borne in mind by the student:—

1. Always begin testing with a weak convex lens, and do not use a concave until you are absolutely positive that the weakest convex lens makes vision worse.

2. Always test distant vision first; then for reading.

3. If a person sees as well for distance with a plus lens as without it, he requires that lens.

As it is now fully understood by my reader that the Hypermetrope uses his accommodation constantly, it cannot, therefore, be expected that placing a weak convex lens before the eye will cause it to relax at once. On the contrary, the usual tendency, if the patient is young, is for the Ciliary muscle to contract, and thus make the Crystalline Lens more convex, either entirely or partly disguising the defect, or possibly over-correcting it, and simulating Myopia (Spasm of Accommodation). In either case, it will prevent the refractionist from obtaining a satisfactory correction. For this reason, then, it is necessary in Hypermetropia to be confident that the accommodation is under control before proceeding to test, and this is only possible by paralysing the Ciliary muscle—not necessarily by means of a cycloplegic (in fact, the author is very strongly opposed to the use of drugs by others than a properly qualified medical man), but by means of a convex lens.

There are two methods of testing: one in which you do not paralyse the accommodation, but commence with the weakest convex lens, and gradually increase the strength until you obtain the strongest with which the patient can see normally; and the other is the method of paralysing the accommodation by means of lenses, which is the way generally adopted by myself. The first is, of course, more reliable in cases of middle-aged people; as then the accommodation is naturally weakened, and is not, as a rule, strong enough to interfere seriously with the testing. Below are given both of these methods, so that the reader may select for himself, which procedure he thinks is the better.

ROUTINE OF TESTING.

Place your patient at the appropriate distance from the test type (in this case let us assume the distance is six metres, or twenty feet). Place the trial frame on patient's face, adjusting it (by means of thumbscrews placed on either end of the front, for the purpose) so that the pupils of the eyes are looking through the centres of the frame. Now put a blank disc in front of the left eye (always testing the right one first), so as to test each eye separately. You must find your patient's acuity of vision, by asking him to read the smallest letters that he can see distinctly on the test types. Say, for example, that the lowest he can read are letters which should be read by the normal eye at twelve metres (V. $= \frac{6}{12}$ or $\frac{20}{40}$). The type he should see at six metres, of course is the one marked on the test card "six metres or twenty feet." You now place in front of patient's eye a + 1D. lens, and ask him if he sees the letters on the chart any better than without it—if he should answer "Yes," you know that he suffers from Hypermetropia. Then place in the trial frame a + 1·50 D. lens, and ask him if this is also an improvement on the last glass; if vision is sufficiently improved that he reads $\frac{6}{9}$, you try a stronger convex lens, say + 2D. If this makes vision equal to $\frac{6}{6}$, you try a still stronger

lens, a + 2·50D., and if this makes the vision blurred, you will then know that it is too strong, and that the lens just weaker than this is the correction of the Manifest Hypermetropia. You therefore give your patient + 2·25D. for distance, for the right eye. You must now test the left eye in the same manner.

Always remember, in Hypermetropia, to give the strongest convex lens which gives best results or normal vision. If there should be any doubt as to which of two lenses gives the better result, always prescribe the stronger. For example, if a + 1·50 and + 2D. give the same result, you should choose the + 2D.

For reading, in Hypermetropia, if the accommodation is strong enough, you give the same lens as for distance. You find this out by giving your patient the reading test card, and asking him to read the smallest type on it with his distant correction on; if he can read this, his accommodation is strong enough, and you therefore prescribe his distance correction to be worn constantly.

In theory, this sounds perfection itself, as by giving the distance correction you enable parallel rays to be focussed on the Retina without any effort of accommodation being brought into play; *i.e.*, the eye is at rest, as in Emmetropia, and for reading you allow the patient to add to the convexity of his lens by accommodating, in order to overcome the increased divergence of the rays coming from the reading distance. This also is precisely what happens in Emmetropia—the eye is at rest when observing distant objects, but it has to accommodate when regarding those near by.

In practice, however, it is often found that the accommodative power is deficient for this purpose; owing to the Ciliary muscle being so constantly exerted that the nervous energy distributed to it is more or less exhausted; so that the distance glasses are not strong enough for reading. It becomes necessary, therefore, to add to the distance correction (which in the example just given is + 2·25D.) a convex lens of sufficient strength to enable the patient to read comfortably the smallest

line of letters on the reading test card, at a distance of thirty-three centimetres (or thirteen inches). Of course, if the patient wishes to read further off than thirty-three centimetres (thirteen inches), you would add a weaker lens; or, if nearer than this distance, a stronger one. The addition usually required is about one-third more than the distance glass; however, it is really impossible to give any fixed rule as regards this, as it depends entirely upon the amount of *available* accommodation the patient possesses, and this varies in almost each individual case. Since it is impossible to formulate any cast-iron rule in the above connection, you cannot do better than govern yourself by Nature's intent. As it is quite natural for the eye to accommodate for reading, in those cases where assistance is necessary, add as little more convex power as possible to the distance glasses, so as to allow the Ciliary muscle to exert as great an effort as can be comfortably maintained. Otherwise, if you give too much extra assistance for reading, you upset the perfect harmony existing between the two eyes, by suppressing a natural function. Should the Hypermetropia be *facultative*, it is not absolutely necessary that glasses be given for constant use, although it is better to do so. In some cases they need only be given for reading, writing, sewing, and other near work, no lens being prescribed for distance. As a guide, I may tell you that, generally, patients having a near point of fifteen centimetres, or nearer, will accept the same glasses for reading as they require for distance; and that if their near point is beyond this distance, two glasses will be necessary, the weaker of the two being the distance pair. The punctum proximum, or near point, can be ascertained by asking the patient to see how close to his eyes he can read the small type of the reading card, and measuring the distance with an ordinary tape measure or metre rule, whichever you happen to have by you.

After one has tested a case, and found the strongest convex lens with which the patient sees well, this does not represent the total amount of his Hypermetropia, but merely all the

manifest error. The amount of *latent* defect you will be unable to ascertain (as you cannot use drugs to tie up the accommodation), until the latent Hypermetropia becomes manifest with age, which is accelerated by the use of the convex lenses for the manifest error; but by adopting the "paralysing" system of testing, you will be able to obtain the strongest possible correction that the patient can wear.

There is, however, no great disadvantage in being unable to estimate the latent defect as well as the manifest error, because even if you knew the amount, you could not give the patient to wear more than that which corrects the manifest amount of the defect, allowing perhaps a little for the latent. I will endeavour now to explain thoroughly to my readers the method of conducting the "Paralysing" system of testing for Hypermetropia.

The Paralysing System of using the trial lenses is the only method which enables the refractionist to test a case of Hypermetropia, knowing that the Ciliary muscle is at rest, without the aid of cycloplegics:—

1. Place your patient at the correct distance from the test chart: which, if you can conveniently afford the distance, is six metres—if not, 4·5 or three metres will do; but never placing the patient nearer than three metres.

2. Adjust the trial frame so that the pupils are perfectly centred; that is to say, exactly in the middle of the eye-rims of the trial frame.

3. Cover with the blank disc the left eye, in order to test each one separately, commencing always with the right eye. After testing an eye, one must jot down the correction on paper, before proceeding to test the other; as it is not advisable to trust one's memory in such a matter—and should you omit to put "R.E." or "L.E." before the combination, you will know that the first correction is for the right eye, as this was the one you first tested.

4. Direct patient to look down the chart, reading out the

smallest letters he can clearly discern. In this way you note his visual acuity.

5. Commence the test by holding a weak convex lens in front of the right eye. If this makes the vision better, or no worse, it signifies Hypermetropia. (The power of this lens depends upon the acuteness of vision. If the defect seems only slight, + 0·50 will suffice; but if patient's vision is much below normal, a stronger lens may be used to advantage.)

6. Now place in the *front* cell of trial frame a convex spherical lens of sufficient power to thoroughly blur the vision; so that patient cannot see better than $\frac{6}{60}$, or the largest letters on the chart indistinctly. Inform him that he must look through this strong convex lens (the "paralysing" lens) constantly at the chart, and endeavour to see the letters on the card through it; and not turn the eyes to nearer objects—as if he does, it will stimulate the accommodation into action, and thus interfere with the test.

7. Then begin by holding in front of this strong plus lens a −0·25 sph., and then a −0·50D., and ask patient if this improves the vision (of course, the stronger concave lens will improve it the most). Now gradually increase the strength of the concave spheres by −0·25D. at a time, until vision is *nearly* as good as with the naked eye. A good plan in reducing the paralysing lens, is to deceive the patient occasionally by placing the same concave lens before the eye *twice* (of course without his knowledge), instead of increasing the power; because the patient, after a little practice, is expecting an improvement at each step in the testing, and may answer automatically, as it were, without paying much attention to what he really does read. If the paralysing lens is + 5D., and by our test we find that − 2·25D. held in front of it enables the patient to see $\frac{6}{9}$ indistinctly; and with the naked eye he also reads this line, only clearly, you finish. (There is one exception to this rule; that is, when the patient's vision *without* lenses is very poor, say, $\frac{6}{30}$ or $\frac{6}{24}$, when you would try to bring the vision up to $\frac{6}{6}$, if possible. The

patient having very bad vision is proof that he cannot be overcoming his defect with his accommodation; therefore there is no necessity to allow for it, as you would have to do when a hypermetrope possessed good vision, such as $\frac{6}{9}$ or so).

Now the difference between the $+5$D. and the $-2{\cdot}25$D. will be the correction; therefore place $+2{\cdot}75$ sph. ($+5{\cdot}-2{\cdot}25=+2{\cdot}75$) in the *back* cell of the trial frame, *before* removing the paralysing lens. You now find the reading glasses, as explained before in the former procedure of testing. The reason I advise the correcting lens being placed in the *back* cell of the trial frame is, because a convex lens, on placing it farther away from the eyes, gains in strength; and consequently might not afford such good vision to the patient as if it had been placed nearer to the face.

Remember that if a patient can see as well, at a distance, with a convex lens as without it, the lens cannot be too strong. The danger in testing for Hypermetropia is to *under-correct* the defect—you cannot give too powerful a convex lens, in fact, a good rule to follow, if the patient is young, is to add $+0{\cdot}25$ or $+0{\cdot}50$D. to the plus lens which is found necessary for distance; and in this way *over-correct* the amount of error. After using the glasses for a short time, the accommodation will have relaxed, having become accustomed to the changed condition; and the patient will then be able to see $\frac{6}{6}$, although possibly, when you first prescribed the glasses, he could see $\frac{6}{6}$ indistinctly, or perhaps only $\frac{6}{9}$.

A very useful method of unmasking a stubborn case of Hypermetropia in which the accommodation is more than usually active; after ascertaining that the visual acuity of both eyes is equal, is to test binocularly, and place a pair of weak prisms, *bases in*, before the eyes, so that a constant divergent effort must be maintained in order to see the letters on the distance chart singly. Owing to the intimate connection between accommodation and convergence, this restraining influence upon the internal recti induces a

corresponding relaxation of the Ciliary muscle; so that, by placing plus lenses before the eyes, under this present control, a degree of Hypermetropia can be corrected which would have baffled the refractionist under ordinary conditions of testing.

Another good plan to overcome an obstinate accommodation is, to indulge in prism exercises (encouraging divergence), by means of gradually increasing prisms, bases in; continuing as long as single vision is maintained at a distance. When Diplopia results, commence over again, from the original number of prism. A short course of such treatment has been known to give excellent results, and saves the patient from the inconvenience of atropine.

It is advisable to have no person but the patient in the room with you whilst testing; but if you do admit any one, it should be on the strict understanding that they take no part in the proceedings.

After having tested the right eye, and found the correction, remove the blank disc from the left eye and place it in front of the right, leaving the correction behind it. Then proceed with the left eye as usual; after which remove the blank disc from the right eye, and try the binocular vision (that is, the vision of both eyes together). It will be found that binocularly, a hypermetropic eye will accept a stronger correction than when the eyes are tried separately. So you endeavour to add an equal amount to each eye, as much as possible without interfering with the vision—begin with, say + 0·25D., and increase, if you can, to perhaps + 1D., or as much more as possible. The reason of this is, that when the two eyes are used in binocular vision, regarding an object situated at infinity (over six metres or so), there is no convergence at all; any tendency being suppressed, so as to avoid the double vision which would otherwise result. Consequently the accommodation, owing to its close association with convergence, is at the same time more or less relaxed, and the amount of manifest Hypermetropia necessarily increased; whereas in monocular

vision (using only one eye), it would be possible to converge, without interfering with the distinctness of the sight; which effort has a reflex action upon the accommodation, increasing that also, and thus disguising a greater amount of the error.

This applies equally to Myopia, inasmuch as if there is a certain amount of accommodation when the eyes are used separately, it must increase the apparent defect, and the patient accepts a stronger concave lens than is really necessary; but on looking with both eyes together, this accommodation has relaxed—therefore you will be able to weaken your correction slightly (see chapter on Myopia).

If there should be a difference in the refraction of the two eyes (Anisometropia, or unequal vision), and it is so marked that when the eyes are used together it causes discomfort, we must try to equalise the corrections of the two eyes; and in Hypermetropia it is preferable to add to the weaker correction, making it more equal to the stronger one. If the alteration to be made is considerable, then you will have to add to the weaker lens, and take a little from the stronger as well. It is not necessary to make them exactly the same; but you would alter them sufficiently to dispel the unpleasantness complained of by your patient.

It is frequently the case, if a patient has not been wearing glasses previously, that your prescription, although the right one, may be too strong, and the patient unable to accustom himself to them; in which case, you would not give him his full correction, but would only partly correct his error, and as he became more used to wearing glasses, increase this strength until you arrived again at the original amount.

Symptoms.—Before commencing the *rationale* of testing, as described above, it is advisable to pay attention to the patient's complaints and the reasons they have for coming to you, as their explanations often help one in diagnosing their defect.

A hypermetropic patient usually sees well at a distance,

but experiences a difficulty in maintaining clear vision when reading. The words may run together, or become dim and blurred, so that the patient must stop his work and rest the eyes before he is able to continue what he was doing; and on resuming his reading, after a short time there is a repetition of the dimness, and again he is compelled to give up his work. The eyes often ache and water; there is sometimes a feeling of heaviness about the lids—the eyes appear red and weak. Headache is a prominent symptom of Hypermetropia; also sick headaches are largely due to eye-strain. The patient also often complains of being unable to stand a strong light, as it seems to hurt his eyes.

The characteristic points in which a hypermetropic eye differs from an emmetropic one are, that it looks smaller, the Sclerotic is flat, the lens and iris appear forward, the anterior chamber shallow, and the pupil small. The patient's face also bears indications of the defect; the eyes are small and deeply set in the head, and the face flat; there are lines on the forehead, which would indicate constant frowning. There is also a tendency to remove the paper or reading matter beyond a comfortable distance; and a very frequent symptom among children is a dulness of learning.

However, it is not intended that the student should rely wholly on these indications, as they are very far from being infallible; and I have had several cases, personally, of Hypermetropia, in which there were none, or very few, of these symptoms present. But they are merely given in the hope that they may facilitate his diagnosis of a case.

Every defect has the tendency to excite other affections, alike in nature or association; and Hypermetropia is by no means an exception to this rule.

The amount of nerve-force it is necessary to send forth from the brain to the Ciliary muscle, so as to bring about the accommodation, regulates the supply given to the internal Recti muscles. Thus, imagine an eye is directed to a point one metre

(forty inches) distant. The convergence necessary to maintain binocular vision involves a certain strain upon the nerve supplying the internal Recti muscles of both eyes; and this necessitates a corresponding amount of effort on the part of the Ciliary muscle in *each* eye for accommodation. It may, therefore, be estimated that for every effort on the part of the Ciliary muscles in the two eyes, there is an additional strain of half that amount for convergence.

Convergence is the power of directing the visual axes (*i.e.*, imaginary lines drawn from the macula to the object observed), of the two eyes, to a point nearer than infinity; and is brought about by the action of the internal Recti muscles. As soon as the necessity for convergence is gone, the supply of nerve power to the internal Recti is closed at the nerve centre (the brain); and the nerves that supply the external Recti are brought into action, causing these muscles to contract, so that the visual axes resume their natural direction. Thus it is seen that the internal Recti receive automatically one-half as much nervous energy as is given to the Ciliary muscles.

Now it is a well known fact that a Hypermetrope can overcome his defect by bringing into play the little muscle which regulates the convexity of the Crystalline Lens, and thus obtain remarkable vision; but it will be seen that this involves a great waste of nerve-power. In Hypermetropia of, say, 1D., a certain amount of nervous energy is sent continually to the Ciliary muscle whilst the patient is awake, in order to overcome the defect and preserve good distant vision; and this effort on the part of the Ciliary muscle necessitates the convergence in natural proportion, as we have just seen.

Now, in order to prevent this converging tendency, there must be a corresponding amount of power sent to the external Recti; otherwise the convergence would interfere with binocular vision—as, when looking at a distance, the eyes are not required to converge, but should be parallel. This enormous excess of nervous energy above that of the emmetropic eye (which is

normally at rest when looking at a distance) is going on continually during the sixteen hours of wakeful life; and if the nerve centre (the brain) be only capable of distributing about the whole of the body a certain amount of nervous energy, the excessive demand caused by the patient's endeavour to overcome his Hypermetropia must necessarily come from the reserve supply in the brain; and it is when this is exhausted, through the continual drawing upon it, that the trouble of other of our functions begins.

As we all know that the digestive organs are very dependent upon the nervous system, we need not be surprised to learn that ocular irregularities will cause discomfort in that region; in fact, a frequent result of Hypermetropia is the disturbance of the digestion, as the stomach obtains its necessary supply of nervous energy direct from the brain—and if the eye receives more than its natural proportion, the general supply to other of our faculties must suffer, provided they obtain their stimulus from the same centre, which happens in this case; and the stomach fails to obtain its necessary amount. Thus it is obvious that, in time, the entire system would become involved, if this unnatural waste of nervous energy is not prevented, by prescribing the necessary lenses to correct the Hypermetropia, and in this way preventing leakage.

This defect is also the not infrequent cause of Convergent Strabismus (squint). For instance, if the hypermetrope wishes to see distinctly at a distance, he is bound to exert a considerable amount of accommodative effort; and when looking at near objects, the strain must be still greater—because, as the eye is too short antero-posteriorly, the rays of light would focus behind the Retina (if it were possible for them to penetrate the tunics of the eye), and the Ciliary muscle must be brought into play, if clear vision is to be obtained. As was previously explained, the accommodation and the convergence are very closely associated; and what calls the one into action, at the same time, and within certain limits, brings the other. There-

fore, when a patient exerts an excessive amount of accommodation, he must at the same time call into action an excessive amount of convergence. Occasionally when this is done, the internal muscles over-act, and one eye (generally the weaker one) turns in too far—that is, squints inward, or converges—whilst the better one is directed on the object. The image formed on the Retina of the deviating eye, which is very faint and indistinct, is suppressed by the brain. Thus binocular vision is sacrificed, in order that the image recognised by the brain may be clearly and well defined.

Headache is very frequently the direct result of Hypermetropia; it also causes inflammation of the lids and congestion of the blood-vessels of the conjunctiva or mucous membrane which covers the front of the eye. The friction brought about by the continual working of the Ciliary muscle which operates the Crystalline Lens promotes congestion of the blood-vessels in the vicinity, and fever is the result; which, on account of its proximity, extends to the outer coats. The individual now, as likely as not, goes out of doors, and the cold air chills the nerves surrounding the exposed vessels and glands, causing them to contract, preventing the circulation of the blood and discharge of matter; thus causing not merely inflammation, but also granulated lids. These affections of the eye are looked upon by many as diseases; but, as explained above, they are not—although, if long neglected, they will soon become diseases, and will be infectious. In cases such as those just mentioned, order rest from any near work for a short time, and prescribe a little salt water lotion to be applied to the eyes two or three times daily; and a pair of accurately fitted glasses, which will be found to afford the patient permanent relief.

In summing up the evil effects of uncorrected Hypermetropia, they are seen to be somewhat varied; the hypermetrope either sees badly—in which case, since the eyes are at rest, he suffers no other inconvenience—or he sees well by virtue of his accommodation. When this is so, the accommo-

dative effort involves convergence in natural proportion; but the desire for single binocular vision is so great, that by an effort of will the externi are exerted, and so counteract the inward tendency, thus maintaining clear single vision—the result of this being headache, or other reflex conditions, but *not* squint. If the eyes are eventually unable to maintain this continual strain, then Strabismus (squint) becomes manifest.

The following is an additional method by which to measure the degree of Hypermetropia:—

It has been previously explained that the amplitude of accommodation gradually decreases in strength as age advances. Now, you must remember that in Hypermetropia a certain amount of this accommodation is used in the endeavour to overcome the defect and maintain good vision at a distance; consequently, when the hypermetrope brings his eyes to view near objects, he does so at a disadvantage compared with the emmetrope, to the extent of the degree of his Ametropia. Because, say, for example, that his Hypermetropia is + 2D., and he sees perfectly at a distance by exerting his Ciliary muscle, he must bring into action 2D. of accommodation to do so, and when regarding objects close to him, he necessarily has 2D. less accommodation for the purpose than an emmetrope of the same age; that is to say, if an emmetrope of twenty years has 10D. of accommodation, his PP (near point) is ten centimetres (see Table, p. 81), while a hypermetrope of 2D. at twenty years of age would only have 8D. of his accommodation left for regarding near objects, as he uses + 2D. to overcome his defect for distant vision. Thus, his available amount is deficient, compared with that of an emmetrope of the same age.

From the above it is obvious *that any deficiency in the power of accommodation at any age represents the amount of Hypermetropia present.* Examples:—

1. A person of ten years of age, with + 3D. of Hypermetropia, instead of having a near point of seven centimetres,

as an emmetropic person would, could not see nearer the eye than nine centimetres; which represents an amplitude of accommodation of 11D., and a deficiency of 3D. compared with that of an emmetrope of ten years.

2. If, on measuring a patient's near point, it is found to be fourteen centimetres, this represents an amplitude of 7D. Now, if patient's age is twenty-five years, this would represent a deficiency of 1·5D.; which indicates a degree of Hypermetropia of + 1·5D.

This method is merely an approximation of the amount of the error, but it will be found very useful as an auxiliary test. Also, to corroborate your trial case result, estimating the near point is of value. This can be accomplished in two ways:—Testing each eye singly, find the near point without any lenses before the eye; and the amount of deficiency of accommodation should correspond to the dioptric value of your trial case correction. The other method is, to ascertain the near point with the lens found by your previous test before the eye; and if this has been accurately estimated, the near point will be at the distance indicated by the patient's age, according to the table given on page 81. If it does not so correspond, then your correction is either too powerful or too weak, as the near point is found to be nearer to, or farther off, than the average distance for the patient's age. In young people, where the accommodation is powerful, the variation in the near point is very little to produce big differences in the amplitude; so that, by taking the near point measurement through a concave lens, and making allowance for it in the result, the accommodation is reduced, and the measurement made easier and more accurate.

If patient is ten years old, the near point should be at 7 c/m., and one centimetre nearer or further off makes a difference of 1·50D.; whereas, by reducing the accommodation five dioptres with a −5D. lens, the same difference is represented by 5 c/m. nearer or 7 c/m. further away respectively—which is

surely easier to read off the Near-point Rule than a variation of 1 c/m.

SUMMARY OF TESTING.

1. After listening attentively to all the troubles of your patient, begin by placing him in a chair at six metres from the test types.

2. Put on and adjust the trial frame, so that the patient is looking through the centres of the frame.

3. Place the blank disc in front of the left eye.

4. Find the acuity of vision by ascertaining the smallest line of letters that the patient can easily distinguish on the distance test chart.

5. Hold a weak plus lens in front of the right eye. If this *improves* vision, or makes it *no worse*, it shows Hypermetropia.

6. Place in front cell of trial frame a strong convex lens, so as to tie up or paralyse the accommodation.

7. Instruct patient to look through the strong lens all the time you are testing.

8. Reduce its strength slowly, by holding before it a − 0·25D. sph., and gradually increase the power of the concave sphere by 0·25 at a time, until the patient sees nearly as well as with the naked eye.

9. Now the difference between the strong convex lens and the concave is the correction, which place in the back cell of trial frame, *before removing* the paralysing lens.

10. Test the left eye in a like manner.

11. Try the binocular vision, that is, the two eyes together; and increase the correction equally in each eye, if possible.

12. After finishing the two eyes for distance, then test them for reading. If possible, give the same lens for both purposes; if not, a slightly stronger glass is necessary for reading.

The above routine of testing gives the "paralysing" system. If the student does not intend to use this method in every case of Hypermetropia, I should anyway strongly advise

him to do so in all cases of children, and in those in which people come to him complaining of some unpleasant effect, such as inflammation of the lids, or any other affection that may be caused by this defect.

IMPORTANT RULES GIVEN IN THIS CHAPTER.

1. Distant vision should be tested first, before reading.

2. Always test each eye separately, beginning preferably with the right one.

3. Always commence testing with a convex lens, never with a concave.

4. Only a Hypermetrope will be able to see as well or better through a convex lens as without it, for distance.

5. If a person sees for a distance as well with a plus lens as without it, that lens cannot be too strong.

6. Always prescribe the strongest convex lens for Hypermetropia that gives the best result at the distance test.

7. Give the distance glasses for constant use, if possible; otherwise, add to same as little as necessary for comfortable reading.

8. If a person sees $\frac{6}{6}$, it is not proof that his eyes are Emmetropic; they may be Hypermetropic, using the accommodation.

9. Never, on any account, hurry through your testing, but take your time, and be sure of your results.

10. A Hypermetrope's near point is always further from the eyes than an Emmetropic person's.

11. Remember that it is not always possible to bring your patient's vision up to $\frac{6}{6}$ in every case; there are some that you can only partially correct. In these cases you advise patient to come again, after wearing your correction for some little time, when you may obtain a more satisfactory result. Of course, if you have reason to suspect any disease, you should, without any hesitation, send your patient to an oculist, as this is beyond you; and if you attempted to prescribe for it, you would be trespassing on the domain of the medical man, which you should always avoid doing.

CHAPTER VII.

MYOPIA.

It will considerably assist the beginner in refraction work, if he remembers that Myopia is in every respect the direct antithesis to Hypermetropia, or long sight; in fact, if he reverses all that has been stated in the last chapter, he will practically know the theory of Myopia.

Well, to begin with, a myopic eye, instead of being too short from the front to the back, is too long on its antero-posterior diameter; so that parallel rays of light, instead of being focussed on the Retina, come to a point in front of it, in the Vitreous Humour which fills the large posterior cavity of the eyeball, where the rays cross, and meet the Retina after they have been focussed, and consequently impair the vision.

Myopia, then, is, in other words, that condition of the eye in which the sensitive layer or Retina is situated beyond the principal focus of the "Refractive Media"; the eyeball being longer than nine-tenths of an inch, or 22·824 millimetres.

This is a condition in which the individual can absolutely do nothing to correct his defect; because the eyes are at rest—that is, the Ciliary muscle is not exerted—as any effort on the part of the accommodation would only cause the rays of light to focus shorter, that is, still further away from the Retina, and make the vision worse than before. The only way in which the defect could be improved, would be to lessen the refractive power of the eye; and there is no way in which this can be accomplished as the Crystalline Lens has its least degree of

curvature, and there is no mechanism by which to flatten this, and so make it less convex than when it is in repose. Then the eye itself can do nothing to improve its condition.

However, myopes (*i.e.*, short-sighted people), in order to better their vision, have the habit of bringing the eyelids together, so as to shut off the circumferential rays; and in this way diminish the circles of diffusion which are caused by the poorly focussed rays on the Retina. This is the reason for the term "Myopia" being given to this error of refraction, as it means "to close the eyes," and not "near sight," as many imagine. A better and more appropriate name, suggested by Donders, is "Brachymetropia"—which is a literal translation into Greek of "short sight." This, however, was never brought into general use; possibly for the reason that it was the better name of the two.

It is obvious, from the foregoing remarks, that as the Retina is situated further back than the focus of the parallel rays of light, the nearer an object is brought to the eyes, and the more divergent the rays emanating from it, the better the myopic person will see; because, as the rays become more divergent, the closer the object approaches the eye, they will focus gradually further back, and, consequently, when the object comes to a certain distance from the eyes, the rays will meet exactly on the Retina. This distance is called the far point, or Punctum Remotum (PR) of a myopic eye; and it represents in centimetres the exact amount of the Myopia—which you can reduce to dioptres by dividing the centimetres into 100; or if this distance is obtained in inches, by dividing into 40.

In Fig. XLVII. you see the parallel rays P, P^1, entering a myopic eye, and focussing in front of the Retina, as at *f*; but the divergent rays emanating from an object situated at PR are focussed exactly on the Retina at F. PR then represents the far point of this Myopic eye. If the distance from the eye of the Punctum Remotum was fifty centimetres, it would represent a Myopia of 2D. ($\frac{100}{50}=2$). It is seen, therefore,

that at a certain limited or definite distance in front of the Myopic eye, rays of light from an object have just sufficient divergence to be focussed upon the Retina—this distance being termed the far point. The far point and the Retina then, are conjugate foci; that is, rays emanating from the far point focus upon the Retina, and rays diverging from the Retina focus at the far point.

The fact that the nearer an object comes to the eye the better it is seen by the Myope, points out that the short-sighted eye is adapted for divergent rays. In this defect, the mechanism of accommodation is used very little—or rather it is not used at all, until the object is brought closer to the eye than its far point—therefore, if the Myopia is of moderate or

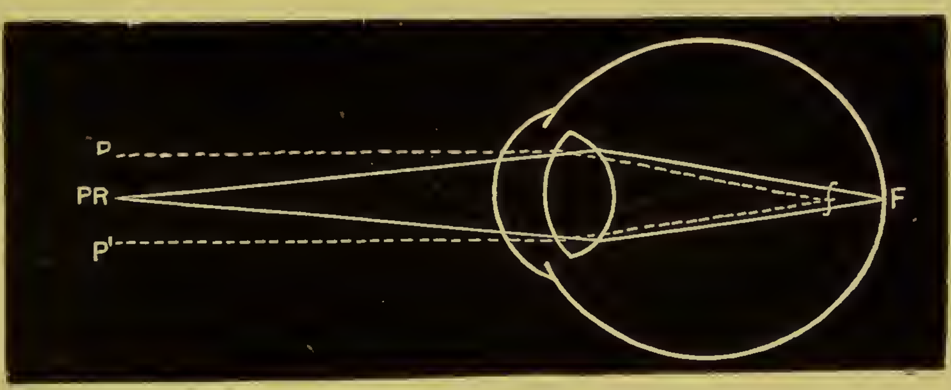


FIG. XLVII.

large amount, it is correct to assert that the accommodation is practically not in use at all. For this reason we will state that the Myopic eye is always at rest.

Causes of Myopia :—

1. An elongation of the eyeball antero-posteriorly;
2. Increase in the strength of the refractive media of the eye.

This defect is almost invariably dependent upon the abnormal length of the ball; although for a long period it was said to be due to the increased convexity of the Cornea. This statement, however, is quite inaccurate; because, as a rule, instead of there being an increase in its convexity, the Cornea

is less convex. Moreover, the convexity of the Cornea is generally in inverse proportion to the degree of the Myopia; that is, the greater the amount of Myopia, the less the convexity of the Cornea.

Myopia is not congenital like Hypermetropia, as it seldom shows itself earlier than seven years of age. As mentioned before, almost all eyes are Hypermetropic at birth; and they gradually grow, assuming their natural size at about the sixth year—that is, of course, if their development is in no way arrested. Now, Myopia is present when the eye, instead of remaining at the standard or normal size, overgrows itself as it were, and becomes longer than it is natural for it to be, on its antero-posterior axis.

Myopia is usually a very simple error to diagnose and correct; because, as the Ciliary muscle is not used at all, the defect is naturally always manifest, none of it being disguised or hidden by the accommodation. It is obvious, then, that in this condition of the refraction there is no necessity to paralyse the accommodation.

As the Myopic eye is adapted for divergent rays, and concave lenses render parallel rays traversing them divergent, this is the kind of lens used in the correction of Myopia. And unless it be *progressive*, the testing for it is extremely simple.

The natural tendency of Myopia is to increase; although in many cases it is possible for it to remain perfectly stationary. This is readily understood when one recollects that all infants are hypermetropic, and that the emmetropic or normal standard is not attained until about the fifth or sixth year of life. It is obvious that Myopia is the result of this natural growth exceeding the normal limits, and progressing to an extent which places the Retina beyond the focus of the refractive media of the eye. This being so, the error must originally have been trifling; and for an eye to become myopic to the extent of say only 4D., the eyeball must gradually have elongated, and the defect have been at first of slight degree,

slowly advancing to an error of 4D.—thus the tendency of Myopia to increase is established. It is called Progressive or Malignant Myopia when the defect is increasing rapidly and persistently; and when this is the case, it is a very serious matter, and should be looked upon as a disease; and as such, its treatment is beyond the province of the refractionist. Generally, Myopia developes most during school life; as the excessive use of the eyes for near work, under poor conditions, encourages the natural predisposition of the Myopia to increase. After 25 years of age, it usually becomes stationary; as by this time the coats of the eye are not so yielding as in youth.

This malignant condition is when there is an unnatural and steadily increasing growth of the eyeball, which causes the coats to stretch, and the eyeball to be prolonged backwards; with the result that holes are torn in the Retina, forming scotomata (blind spots); and if it is allowed to continue, it may culminate in irreparable blindness. Hence the necessity of all such cases being referred to an oculist.

The rational treatment is rest for the eyes and not spectacles. The patient should not be allowed to strain his eyes, or read by artificial light; and in some cases absolute rest is necessary.

In all cases of Myopia—especially in young patients, when the defect is of high degree—the eyes should be re-tested periodically, about every twelve or six months, or even more frequently, according to the peculiarities of each individual case.

Myopia is more prevalent among the cultivated classes, and those whose daily employment necessitates a close and constant application of the eyes.

As myopic eyes are adapted for divergent rays, concave lenses are used for the correction of this defect, so as to make the parallel rays from distant objects sufficiently divergent to focus further back, and so on the Retina. Then the correction is such a concave lens as will focus parallel rays perfectly on the Retina.

Concave glasses are used because they are thicker towards the edge, and as all rays of light are refracted towards the denser portion of the lens, they would be divergent after passing through them.

If the Myopia is not progressive, and you have corrected the sight accurately, the lenses for the distance will always remain the same until about 60 years of age, when Acquired Hypermetropia will influence vision (see pages 194 and 195); although for reading they will have to be altered somewhat earlier, when the patient approaches the presbyopic period of life. (This will be further and more extensively mentioned in the chapter on "Aged Sight.")

In contradistinction to Hypermetropia, the correction for Myopia is the *weakest concave* lens that the patient can see best with at a distance. The reason for giving the weakest glass possible is, because in Myopia all the defect is manifest; and, therefore, there is no latent error to allow for. The greatest mistake that can be made in testing for this defect is to prescribe lenses that are too strong; as if you do this, it makes the patient artificially hypermetropic. A myope will nearly always accept a lens that is rather too strong, as he would overcome the excess of power by involuntary accommodation, and possibly see better with it for a time, the letters appearing blacker and more easily distinguished; therefore, in testing, never go beyond the first lens you arrive at that gives good results—that is to say, if – 1·50D. enables your patient to see $\frac{6}{6}$, do *not* try a – 2D., to see if this is as good as with the weaker one; because in all probability it will make the letters appear more distinct, and should you not be on your guard, you might prescribe the – 2D., and cause your patient a great deal of injury; which would have been avoided if you had only followed the rule given above. Why the patient sees as well through the – 2D. as the – 1·50D. is, because he overcomes the stronger lens by bringing his accommodation into play, and neutralizes the difference between the two lenses;

in the same manner as a hypermetrope corrects his own defect by involuntarily exerting the Ciliary muscle. So make a point of never giving too strong a lens to a myope.

It is not necessary to repeat all the rules given in the last chapter respecting the method of examination of a patient; but just before giving the rationale of the testing for Myopia in detail, it is requisite that the reader should remember one of them in particular, viz.:—

That one is *always* to begin testing with a convex lens; and not to use concave until it is certain that the *weakest* convex lens makes vision *worse*.

ROUTINE OF TESTING.

Commence, as in Hypermetropia, by placing your patient at the appropriate distance from the test chart; of course, at six metres if possible, but should this distance be inconvenient, at 4·5 or even three metres, though never closer than this latter distance.

Fit the trial frame on your patient's face, adjusting it so that the pupils are central, and place the blank disc before the left eye. Then ask patient what line of letters on the chart he can read; so as to record his visual acuity.

Now hold in front of his right eye a +1D., and ask him if this improves his sight or not. If he says it makes it more blurred, you know this lens will not do, and you therefore try a weaker one, say + 0·50D.; and if, on asking patient whether this improves his vision, you obtain a negative reply, you place in front of his eye a still weaker lens, +0·25D. If this makes his vision worse than without it, you suspect Myopia, and hold before the eye a – 0·50D. sph., and should this improve the sight, it indicates Myopia.

You now gradually increase the strength of your concave lens by 0·50D. at a time, until you obtain the first one that enables the patient to read $\frac{6}{6}$, or that gives best results. I say the *first* lens; because as you are working upwards, beginning with the weak numbers, the first lens that you come to which

affords normal vision would naturally be the *weakest* one, and is what you require. It is always advisable, in Myopia, to give about 0·25D. or 0·50D. less than you really find necessary to make vision equal to $\frac{6}{6}$, as there will be less possibility of your over-correcting the amount of the defect, and causing a grievous error.

Another excellent rule in this connection is, when using concave lenses, to ask occasionally whether the lens you are now holding before your patient's eye makes the letters on the chart appear smaller than with the previous one. If it does, it shows that this lens is too strong, and you must give the lens just weaker than this.

It is of the greatest importance to determine, as early as possible, whether the Myopia is progressive or stationary. If it has not increased up to twenty-five years of age, it is not likely to do so, and may be looked upon as stationary. But all cases of -9D. or over may be considered as a disease, and should be carefully watched to see whether or not it is increasing; especially up to the age of about twenty-five years. If the defect is not becoming more marked, all well and good; but if it is, you must caution your patient not to strain the eyes—and it is also advisable in all such cases to send him or her to a competent oculist, who may be readily found in most of the larger towns.

There are cases in which the Myopia is progressive only for a limited period, usually from about eight to twenty-five years, as after this age it is more apt to become stationary, owing to the increased resistance afforded by the layers of the eyeball. In this condition, glasses will be of good service; but it is those cases where the defect is increasing rapidly that are attendant with serious consequences to the patient.

There are two other ways by which we are able to ascertain the degree of Myopia. One is by estimating the accommodation, as was mentioned in a previous chapter, and the other by measuring the patient's far point.

For the first way, the student must remember the table of the amplitude of accommodation at the various periods of life; and also the following rule:

That *any increase in the power of accommodation at a certain age indicates the approximate amount of the Myopia present.*

For example: A patient of twenty years of age has a PP of eight centimetres; this represents an amplitude of accommodation of 12D., or an increase of 2D. over the normal amount at this age—which is the amount of the patient's Myopia. Thus it is shown that the myope's near point (PP) is closer to the eye than an emmetropic person's.

To take another example: A boy of fifteen years, instead of having an amplitude of 12D., which is the normal amount at this age, has the near point situated at seven and a half centimetres; which indicates his accommodation to be 13D., an increase of 1D. above normal, which represents his degree of Myopia.

The near point test can, of course, be used for the purpose of corroborating the trial case results, as in Hypermetropia. If the near point is ascertained without a lens before the eye, then the excess of accommodation found by this method should equal the minus lens indicated as the correction with the test case. When you place your correcting lens before the eye, and *then* find the near point, the indications are opposite to those when the patient is hypermetropic. That is, if the near point is closer than it should be, your correction is too weak; and if the near point is further off than the distance indicated by patient's age, your trial case lens is too powerful, and patient is rendered artificially hypermetropic to the amount shown by the difference between the present near point and what it should have been if at the normal distance.

Example.—Patient's age is twenty years, and the near point through the correcting (?) lens (which we will assume to be -4D.), is at five inches instead of at four inches (see Table,

p. 81); so that patient is (with the -4D.) artificially hypermetropic to the extent of 2D., *which represents your over-correction.* The 2D. is found by reducing the respective near points, 4″ and 5″, to dioptres; and subtracting one from the other.

The other method is by measuring the patient's far point, or punctum remotum; that is, the farthest distance at which he can read the small near type. This is the opposite to the method just explained—which was, to measure the patient's near point, or punctum proximum. You ascertain the patient's far point by handing him a reading card, and telling him to hold it as far away from his eyes as he can, and still read the small type; and then you measure this distance. If the farthest distance he sees it is thirty-three centimetres, his Myopia amounts to 3D. ($\frac{100}{33} = 3$).

These tests cannot be solely relied upon; in fact, they should only be resorted to if any other test is deemed necessary in addition to the ordinary one with the trial lenses, as they only give an approximation to the amount of the defect.

The myope has a habit of bringing his work or reading matter close up to his eyes; and this aggravates his defect, and is apt to increase it, if it has a progressive tendency. The object of giving reading glasses in Myopia is, to make the patient hold his reading further away from his eyes. If the accommodation is strong enough, and the Myopia is under 9D., the distance correction will suffice for constant wear. But on the other hand, if the accommodation of your patient is not strong enough, a weaker lens will be required for reading and close work; because the rays of light, being already somewhat divergent, naturally enough do not require so strong a concave lens as parallel rays would to make them sufficiently divergent for the myopic eye to focus them on the Retina.

A useful rule to remember is, that if the distance glass will not do for constant use, a myope of 4D. or more will require about half the distance correction for reading.

Example.—If a patient has Myopia of -5D. for distant vision, you would give approximately $-2{\cdot}50$D. for reading. Of course, in some cases this may be too strong, and in others too weak—you must always treat a case according to its merits. Do not reduce them more than you are obliged; let the patient use as much accommodation for reading as possible without undue strain, and so work with Nature, and not against her.

Myopes of 3D. or less will not require lenses for reading at all, but must wear them for distance. The reason is this: that a myope of 3D. is able to see distinctly up to thirty-three centimetres from his eyes and if the patient can read at this distance there is no necessity for him to wear glasses, since this (33 c/m.) is the normal reading distance.

Again, if, for example, his Myopia is 2D., he will be able to see distinctly as far as fifty centimetres away from his eyes; and therefore should not require concave spectacles to make him read at thirty-three centimetres; although sometimes weak *convex* lenses may be required to enable the myope to read clearly, if his Ciliary muscle is very weak, and his accommodation exhausted.

So in the event of Myopia of 3D. or less being present, give glasses only for distance vision, excepting in the case just mentioned; but you must thoroughly impress upon your patient the importance of holding the book, or whatever it is that is engaging the attention, at thirty-three centimetres or more from the eyes—never nearer than this. If, in low degrees of myopia, the patient does as you advise, and holds his work away from him, there is no necessity to prescribe glasses for close work; but if he does not, you must give them for reading as well as for distance. In such a case the one pair of glasses generally suffices for both purposes.

In high degrees of Myopia, of 9D. or over, to ascertain the reading correction you subtract from the patient's distance glass a lens whose focus represents the distance at which he

wishes to read; and by so doing, you prevent any accommodative effort being used.

Example.—Patient requires for distance − 11D.; and he wishes to read at twenty-five centimetres, which equals four dioptres. You subtract 4D. from the 11D., and the result is −7D.; and this strength of lens you prescribe for reading. The usual deduction necessary from the distance lens is 3D., as this represents thirty-three centimetres; and this is the distance which you would always advise your patient to read at.

In deep Myopia, owing to the elongated shape of the eyeball, there is often considerable difficulty in converging when reading; in which case, weak prisms, bases in, combined with the near glasses, will be beneficial, as they alter the direction of the rays entering the eye, so that they assume a more parallel direction, in consequence of which the eye turns further outward, and in this way, the convergence is lessened.

In Myopia of 10D. or more, the full distance correction must not be prescribed; it is better to give two or three dioptres less than that really found necessary. The exact amount of the deduction called for varies in each individual case; so no rule can be laid down, but common sense should be exercised.

In this defect, as well as in Hypermetropia, the eyes may be anisometropic; that is, the refraction of the two eyes differ sufficiently to cause pain or discomfort when used together.

Say, for sake of example, that the right eye required −4D., and the left −1D.; and that patient complained of being unable to tolerate the two glasses. You might, until he becomes accustomed to wearing spectacles, alter one eye, making the two more equal.

In Myopia, it is best to reduce the strength of the stronger lens, making it more equal to the weaker one. In the case just given you would reduce the 4D. possibly as much as 1D. or 1·50D., making it −2·50D. for the right eye, and leaving the −1D. in the other.

Of course, it may not be necessary to reduce the stronger lens so much as this; and on the other hand you may have to reduce it more than this amount, in which case it would be better to allow both eyes to share the alteration by adding to the weaker a little, and reducing the stronger, altering this lens more than the other. The change should be just enough to enable your patient to wear the glasses comfortably; and as soon as he has become used to wearing the lenses, you should return again to the original powers required.

It is very necessary, as explained in the last chapter, to always try binocular vision (the vision of the two eyes together) after having tested each eye separately. In the defect now under consideration, you would endeavour to make the patient accept a weaker glass; as it is found that, when both eyes are used together, a weaker correction will generally be borne without interfering with the acuteness of vision. The reason is, that since the accommodation and convergence work in unison, sometimes when one eye is covered during the test, it converges, and so stimulates the accommodation, which proportionately increases the apparent amount of error. On trying the eyes binocularly, this convergence is suppressed, and at the same time a reflex action reduces the accommodation which was working with it; thereby lessening the refractive power of the eye. So you reduce the correction of both eyes equally, by holding in front of them first a + 0·50D. and then a + 1D., and see if this makes any noticeable impairment of vision. If it does not, you increase the plus lens as much as you can; and when you have found the greatest amount you can take away, without interfering with the sight of the patient, you alter the lenses accordingly. Say you have R.E. – 3, and L.E. – 5, and find that + 1 held in front makes no appreciable difference, but that + 1·50D. blurs vision, you prescribe R.E. – 2D. and L.E. – 4D.

In the event of a patient being unable to tolerate the full correction at first, you can always partly correct him; and

after a little while increase it to the original glass you found necessary to accurately correct his defect.

Symptoms of Myopia.—As a general rule, the myope has very good vision for near objects, but distant vision is always impaired. The eyes themselves are large and prominent. The pupils are dilated in young people, but as age advances they contract, and thus somewhat improve the state of the retinal image by shutting off the marginal rays, and in this way lessening the diffusion (as explained in the chapter on Anatomy).

Another characteristic of the myope is, the drawing together of the lids when viewing distant objects.

Another symptom is, that the patient brings a book close to the eyes, in order to see the letters clearly; although this is by no means an infallible test, because hypermetropes (especially children) bring their books very near to the eyes, as it gives them a larger retinal image, although a somewhat indistinct one.

Notwithstanding the fact that a myope's nerve strain is lower than normal, yet its co-ordinating influence with the accommodation and convergence is sufficient to cause the patient considerable annoyance and discomfort, especially if he does much near work. It has even been known to cause headache and other indications of Hypermetropia.

Divergent Strabismus is also often a direct result of uncorrected Myopia. Of course, some myopes learn to dis-associate the functions of the accommodation and convergence; and in such cases the individual is not troubled with squint, unless through some other cause. The manner in which Myopia produces Divergent Strabismus is as follows:—

In looking at objects, whether near or at a distance, if the Myopia is of moderate or large amount, myopes use no accommodation at all, whilst the convergence is excessive, and this function is maintained until the eyes have reached the maximum amount of convergence—when the efficacy and tone

of the internal Recti soon become debilitated; and as they weaken and give way the eyes diverge. The power of the accommodation is unimpaired; but the strength of the convergence is worn out, because the limit up to which the two functions may vary has been abused.

To illustrate in a still clearer manner the way in which Myopia upsets the natural association existing between the two functions so important for near work—the accommodation and convergence—we will take the following calculation, which shows accurately the amount of nerve force in which such an eye is lacking.

It must be understood that in Myopia there is a deficiency in the amount of nerve force sent to the internal Recti, owing to the accommodation not being brought into play (the two functions both being supplied by the same nerve from the brain), as the following example will show. Therefore the internal Recti soon become exhausted, and allow their antagonistic muscles to pull the eyeball outwards, and Divergent Strabismus is the result.

Example.—Myopia of, say 2D., shows that 2D. of accommodation *less* is used in each eye for reading than in the emmetropic state; and this, on account of the constant relation existing between this function and the convergence, means 2D. less convergence for both.

Since the average amount of reading or other exercise of the eyes at a short distance may be taken as three hours daily, and as in the myopic eye this calls for no effort of accommodation, the internal Rectus for three hours receives *less than normal* stimulus; in other words, it is insufficiently exercised, thus losing power and tone.

Is it any wonder that this cannot be maintained for long, and that Divergent Squint results?

By prescribing − 2D. in each eye for constant use, and stimulating the accommodation, we allow the distribution of nervous energy to right itself; and thus remove the cause of the trouble.

It will still further add to the importance of correcting this error of refraction at once, if we remember that the myopes are a studious race, and that consequently the majority of them read for a longer period than three hours daily, causing, of course, a greater strain than the above.

The following is a recapitulation of the testing, and of the more important rules given during this chapter.

SUMMARY OF TESTING AND RULES.

1. Place the patient at six metres from the test types.
2. Adjust the trial frame.
3. Place blank disc before the left eye.
4. Find patient's acuity of vision.
5. Hold in front of the right eye a +1D. sph., and ask if the vision is better with this or without it.
6. If the latter, decrease the strength of the convex lens, until you try the *weakest* plus; when if this makes vision worse, you suspect Myopia.
7. A weak concave sphere, 0·50D., is now held before the right eye, and if this clears vision slightly you know the case is one of Myopia.
8. Then increase the minus lens by 0·50D. at a time, until you obtain the first and weakest one that affords a vision of $\frac{6}{6}$, or gives the best results.
9. The weakest lens that does this is the correction. If there should be any doubt as to which of two lenses gives the better result, prescribe the weaker.
10. Try the left eye in a similar manner.
11. Test binocular vision, and endeavour to reduce your correction equally in both eyes.

RULES.

1. Always test distant vision first, then for reading.
2. If the patient is myopic, the weakest *convex* lens will make vision worse.

3. Always give the weakest concave lens with which you obtain the most satisfactory results.

4. If a person sees $\frac{6}{6}$ or better, you may exclude the possibility of there being any Myopia present.

5. If the reading glass requires to be different from the distance one, it will be weaker; just sufficiently reduced to enable the patient to read without overtaxing the accommodation.

6. Only a myope of 3D. or less will require glasses for distance, but can lay them aside for near work.

7. Never allow a patient who is myopic to read or work closer to the eyes than thirty-three centimetres.

8. If the concave lens you are holding before the eye makes the letters on the test chart appear smaller than with the last one, it shows that this lens is too strong.

9. A myope's "near point" is always closer to the eye than that of an emmetrope.

10. Test both eyes together, after having ascertained their correction separately; and endeavour to decrease the amount as much as possible, equally in each eye.

CHAPTER VIII.

ASTIGMATISM, OR ASYMMETRICAL VISION.

WE now come to consider one of the most common of all errors of refraction; indeed, cases of Hypermetropia and Myopia uncomplicated with Astigmatism are comparatively few. Up to now we have only been dealing with defects in which all the meridians or directions of the Retina have been affected equally. Not so in Astigmatism. This is a state of affairs where, instead of all rays of light focussing evenly on the Retina, as in Emmetropia, Hypermetropia, or Myopia, those entering the eye in one direction are brought to a focus earlier than those which pass through another meridian of the Cornea; in other words, Astigmatism may be defined as that condition in which rays entering through the several meridians of the Cornea are focussed differently in the same eye.

Most beginners seem to have a dread of Astigmatism, and look upon it as the most difficult condition of the eyes that they can be called upon to correct. But there is no reason to regard it in any such light, now that you thoroughly comprehend the theory and testing of Hypermetropia and Myopia, of which, as you will find out later, Astigmatism is but a complication. If, therefore, you bear in mind the few rules given in previous chapters, you will encounter very little difficulty in mastering this defect.

Astigmatism may first be divided into two principal forms: one, Irregular Astigmatism. This nomenclature indicates the

condition in which the refractive power varies in the different parts of the *same meridian;* and may be of two kinds.

"Irregular Lenticular Astigmatism" is the name given to that condition of the eye in which the Crystalline Lens is imperfectly formed, so that its refractive power is not uniform in all meridians.

The second kind is due to opacities of the Cornea, caused usually by dust or some other foreign bodies that may have settled there; and is known as "Irregular Corneal Astigmatism."

Not much can be done with lenses to correct Irregular Astigmatism of any variety, although considerable assistance may be given by letting your patient wear a lens ground opaque all over it, except for a thin slit in the direction where the patient's eye is least affected. This meridian is determined by placing in the front cell of the trial frame the Stenopaic Slit, and slowly rotating it until the patient can see the letters on the distance chart most distinctly; this indicates the best meridian of his eye.

If there should be two or more directions in which the patient can see well, then have a lens of ground glass, with two or more meridians left clear. (These directions are usually at less than 90° apart).

The Stenopaic Slit consists of a circular disc of rubber with a thin slit in the centre about one millimetre in width (see Fig. XLVIII.); and by turning it round in front of the eye, one can easily find out the least ametropic direction.

The second variety of Astigmatism is the Regular form, which may be defined as that condition when the refraction of *one meridian* differs from that of *another in the same eye;* that is to say, rays, for example, falling on the vertical meridian of the Cornea, may be focussed on the Retina; but those entering the horizontal meridian may meet it before coming to a focus, thus making this direction of the eye hypermetropic. The Regular form is by far the commonest variety of Astigmatism,

and the vision can, in the great majority of cases, be brought up to normal by the use of plain cylinders, and sometimes the combination of spherical and cylindrical lenses.

The cause is an unequal curvature of the Cornea. Most cases of Astigmatism are congenital, but it may be due to any operation involving the Cornea or Sclerotic, such as for Cataract or an injury.

In Regular Astigmatism, the meridians of least and greatest defect are always at right angles (90°) to each other. By "meridians of least and greatest defect" I mean the direc-

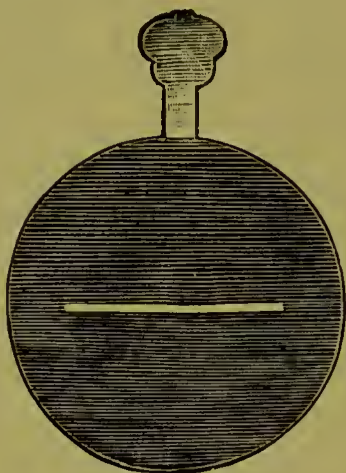


Fig. XLVIII.

tions in which the patient can see worst and best. For example, if patient sees clearest in the horizontal (or 180°) meridian, he will see most indistinctly in the vertical (or 90°) meridian; or if he sees best at 45° meridian, he will see worst at 135°, and so on.

A good rule in this connection is that if a patient sees best at 90°, or in any meridian less than 90° (*i.e.*, 10°, 40°, 70°, or 80°, etc.), you add ninety to obtain the opposite meridian, and if patient sees best in any meridian over 90°, you subtract ninety to find the opposite direction.

This defect is corrected by means of suitable cylindrical lenses, the properties of which have been explained in a former chapter. The axis of the lens—that is, where it is plane glass, and therefore has no refractive power—is placed in the front

cell of the trial frame, in a direction corresponding to the meridian of the least defect in the eye, so that the power or strength of the cylinder may act directly upon the most defective meridian of the Cornea.

Astigmatism is closely associated with Hypermetropia and Myopia. You therefore sometimes require spherical lenses to be combined with the cylinders, in order to correct the long or short sight as well as the Astigmatism. This may be of five kinds :—

Simple { Hypermetropic Astigmatism, Myopic Astigmatism ;

Compound { Hypermetropic Astigmatism, Myopic Astigmatism ;

Mixed Astigmatism.

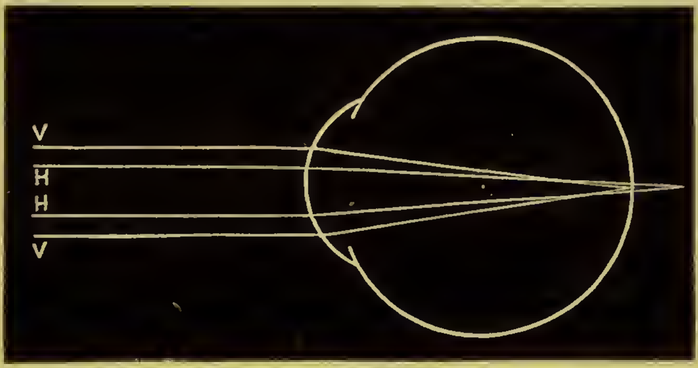


FIG. XLIX.

Simple Hypermetropic Astigmatism is, when one set of rays focusses behind the Retina, and the other (at right angles, or 90°, from it) on the Retina. This is caused through the Cornea having a longer radius, or being less convex, in one meridian (say the horizontal, HH, Fig. XLIX.), while the one at right angles to it (VV) is of normal curvature.

In Fig. XLIX., then, it is seen that the rays VV focus exactly on the Retina, but those entering the Cornea through the horizontal meridian (HH) meet at a point behind the Retina ; that is, the eye is hypermetropic in this meridian, to the extent of, say, +1D.

Now, in order to correct this error, it is necessary to place before the eye a cylindrical lens of + 1D., in such a position that the axis or plane glass is over the emmetropic meridian; that is, the vertical. Then the curve of the cylinder, being over the horizontal, neutralizes the Hypermetropia, making this meridian also emmetropic, and in this way corrects the Astigmatism.

This correction is written in prescription form:—

+ 1 cyl. ax. V.

Simple Myopic Astigmatism is the condition present when the Cornea has too short a radius of curvature, or in other

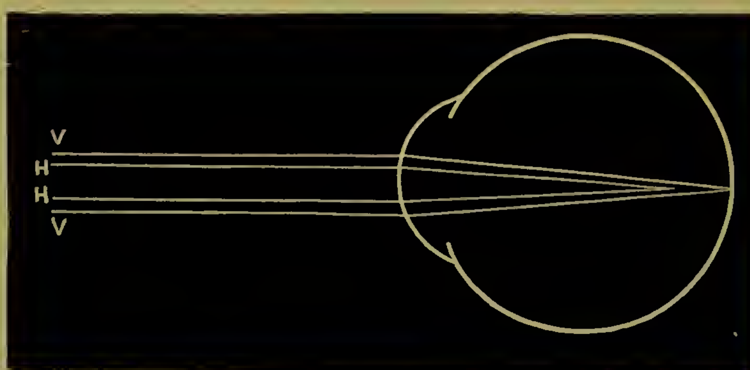


Fig. L.

words, is too convex in one meridian, and of normal curvature in the other. This causes one set of rays—those, for example, falling on the horizontal meridian of the Cornea—to be focussed in the Vitreous Humour in front of the Retina, where they cross before reaching it; and those entering in the opposite meridian, upon it (see Fig. L., HH and VV).

If the Myopia in the horizontal is − 2D., then to render this eye normal, one must place in front of it a −2D. cylinder, with the axis in the vertical meridian. This places the curve of the lens (viz., the −2D.) in the horizontal, and makes this direction emmetropic; and the axis or plane glass is in the direction where no correction is needed; that is, the vertical. This prescription would be written:—

− 2 cyl. ax. V.

Compound Hypermetropic Astigmatism is the most common of all forms of Astigmatism; and is when both principal meridians of the Cornea have too long a radius of curvature, or are less convex than is natural; so that both sets of rays are focussed behind the Retina, but at different distances (see Fig. LI.).

If the vertical meridian is hypermetropic to the extent of + 1D., and the horizontal + 2D.; then to correct the eye we must first reduce it to a case of Simple Astigmatism, by

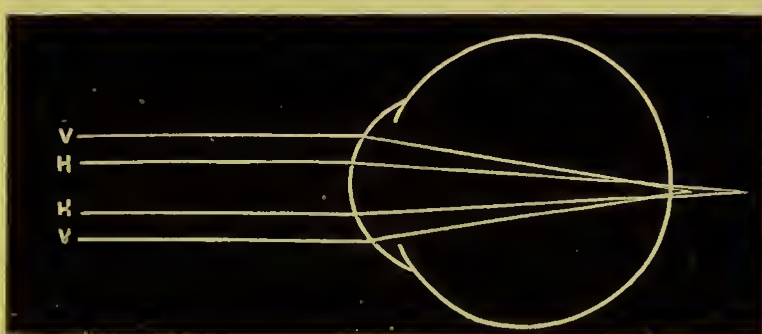


Fig. LI.

correcting the meridian of least defect (the vertical) with a spherical lens; when, as a sphere is curved equally in all meridians, we at the same time partly neutralize the meridian of greatest defect. Then, say we place a + 1D. sphere before the eye in question; we render the vertical meridian emmetropic, and the horizontal meridian, which was hypermetropic of 2D., we reduce to + 1D.; thus reducing the condition to one of Simple Hypermetropic Astigmatism. This you now correct as before described, by placing in front of the eye a + 1D. cylinder, axis in the (now) normal direction, the vertical meridian. So the correction for this defect would read :—

+ 1 sph. $\bigcirc$ + 1 cyl. ax. V.

Compound Myopic Astigmatism.—This is the same condition as just mentioned; only instead of the Cornea being flat, it is too convex in both principal meridians, but more

convex in one direction than in the other. This condition is the most common of all myopic eyes; but when compared with *all* eyes, it takes the second place. In this case, both sets of rays are brought to a focus before reaching the Retina, but at different distances from it (see Fig. LII.). For example, if the horizontal meridian is myopic of 1D., and the vertical meridian myopic to the extent of 2D., the correction would be -1D. spherical; which *fully* corrects the horizontal, but only *partly* neutralizes the vertical meridian; still leaving 1D. of Myopia. This is corrected with a -1D. cylinder; the

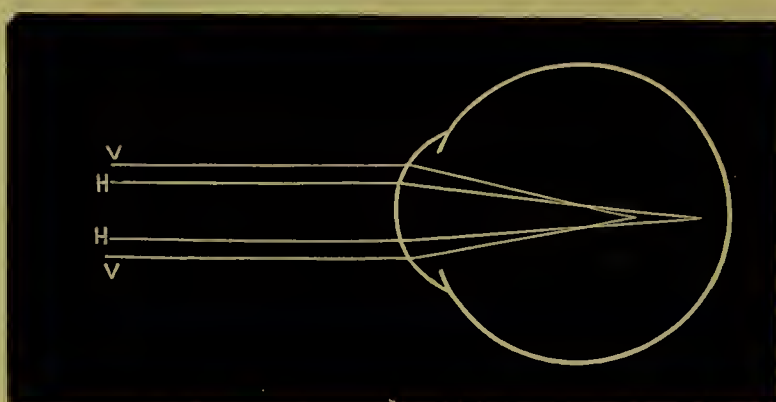


Fig. LII.

axis being placed in the horizontal meridian, which is now Emmetropic. This correction is written:—

$$-1 \text{ sph.} \supset\!\!\!\subset -1 \text{ cyl. ax. H.}$$

Mixed Astigmatism.—Now we have a case where the curvature of the Cornea is greater in one principal meridian, and less in the other, than is proper for the emmetropic condition of the eye; so that the horizontal meridian, say, is hypermetropic, and the other (the vertical) is myopic (see Fig. LIII.).

This defect may be corrected in either of two ways: (1) by means of two cylinders of opposite power, with their axes placed at right angles; or (2) with a convex sphere and concave cylinder combined, or *vice versâ*.

The second is much the better combination; as, if you

remember, it was stated in a former chapter that sphero-cylinders were cross cylinders in effect; consequently there is no necessity for the cross cylinders to be used. However, to show how they could be prescribed in this instance, we will suppose the horizontal meridian of the eye to be ametropic to the extent of +2D., and the vertical meridian −1D. To correct this, you would place a +2D. cylinder with its axis vertical, so as to correct the horizontal perfectly and not alter the vertical meridian; there being still −1D. of defect in this direction, which is corrected by a −1D. cylinder, axis in the

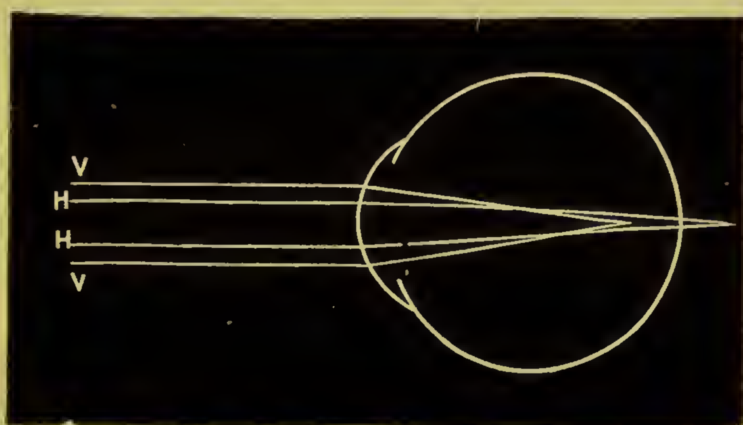


Fig. LIII.

horizontal. This lens corrects the vertical, and does not interfere with the horizontal meridian at all; as the axis of a cylinder has no power. This would be registered :—

+ 2 cyl. ax. V. ⊂ − 1 cyl. ax. H.

Far the better way, though, of prescribing for this eye would be to correct the best meridian with a sphere—viz., −1D. This would entirely neutralize the vertical meridian, making it emmetropic; but as the horizontal is hypermetropic, the −1 sphere would make this direction *one dioptre worse;* that is, +3D. of Hypermetropia, instead of 2D. You therefore use a + 3 cylinder, axis vertical, to correct it; and the prescription is written :—

− 1 sph. ⊂ + 3D. cyl. ax. V.

This Mixed Astigmatism, I may say for the reader's comfort, is not met with very frequently in one's daily practice; but when it is, there is no need to be at a loss as to how to test—as very often the correction is arrived at quite as simply as when testing any of the other kinds of Astigmatism.

From the above it is seen that Astigmatism is a combination of Emmetropia and some form of Ametropia, or of two kinds of abnormal vision, in the same eye.

There is also what is called Normal Astigmatism. This is due to the elliptical form of the Cornea in the standard eye, which makes the vertical and horizontal meridians differ somewhat in length; the former being the shorter of the two. Therefore, even the most perfect eye is astigmatic to a certain degree; but so long as this is not sufficient to perceptibly impair vision or cause discomfort, it is termed the Astigmatism of the normal eye, and need not be taken into account, as it requires no correcting.

In order to give the reader a further insight into the subject, it would be well to explain exactly how a cylindrical lens resembles the curvature of an astigmatic Cornea; and thus show how it possesses the power, when accurately fitted, of neutralizing the Astigmatism.

For instance, take a case of Simple Hypermetropic Astigmatism, in which the vertical meridian is emmetropic and the horizontal hypermetropic of 2D. The defect in this eye is least at 90°, or vertical, and it gradually increases in amount as it approaches the horizontal (0° or 180°); while from the horizontal to the vertical the amount of the error gradually decreases to nothing again, and then increases once more, round to the horizontal (see Fig. LIV.).

Now it should be remembered that a cylindrical lens is plane glass (*i.e.*, has no curvature whatever) in the direction of its axis, and that the greatest strength (and therefore curvature) is at right angles to this meridian, the power of the lens gradually increasing from plane glass (in the axis) to + 2 (if a

+ 2D. cylinder) in the meridian at right angles to the axis; that is, mid-way between these two meridians the strength of the lens would be + 1D., and it increases to + 2 in the horizontal, supposing the axis to be placed vertical; and then lessens again to nothing in the direction of the axis (see Fig. LIV. again).

Thus it is obvious that a cylindrical glass possesses the power of perfectly neutralizing the degree of the Astigmatism.

In the case just mentioned it would be accomplished by placing the + 2 cylinder before the eye, with the axis in the

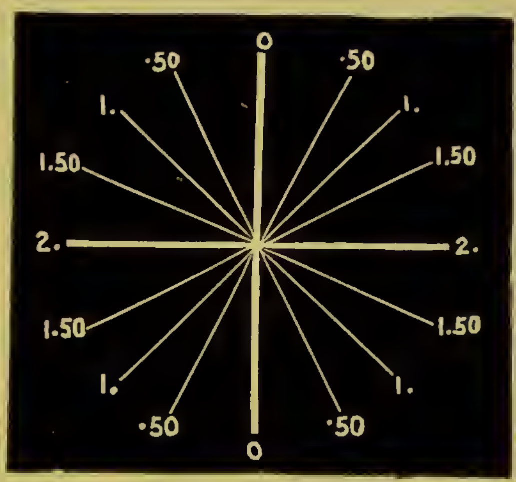


FIG. LIV.
Showing amount of variation of error in a case of Hypermetropic Astigmatism of 2D. in the horizontal meridian.

vertical, which is the normal meridian of the eye; and consequently no strength is necessary in this direction.

It is also seen by the above, that by correcting the meridians of *least and greatest defect* with lenses, we at the same time correct *all the intermediate directions;* for this reason, then, we consider only the two principal meridians in testing.

The effect of this defect upon the vision is principally that an astigmat (one who has Astigmatism) sees objects better in one direction than in another. For instance, looking at the letter "T," an astigmatic patient might mistake it for the figure "1," not being able to distinguish the horizontal line at

the top of the letter. The object in testing for this defect is, to enable your patient to see equally as well in one meridian or direction as in another; that is, to make the vision of the worst meridian of your patient's eye equal to that of his best, and when this is done the Astigmatism is corrected.

The following cuts show very clearly how an astigmatic patient sees an object. The illustration LV. represents the

FIG. LV.

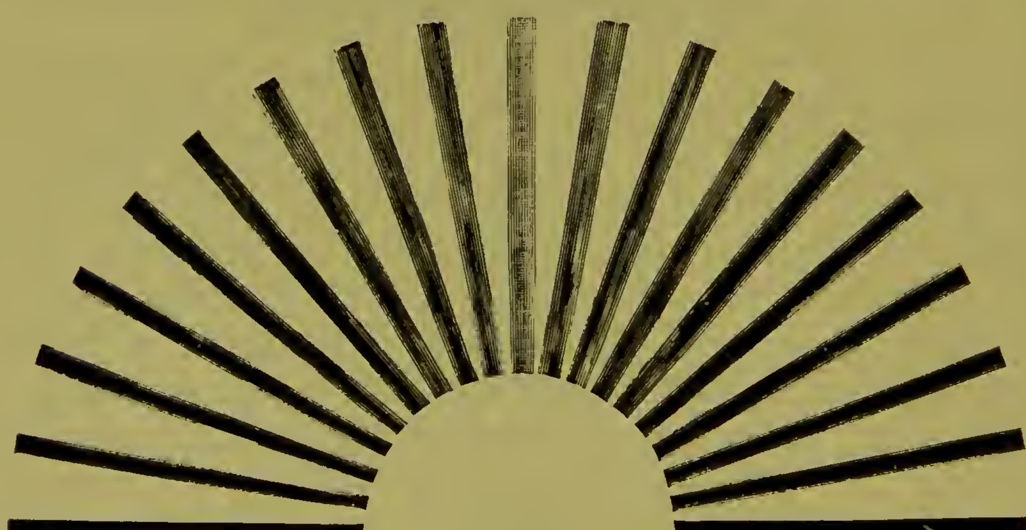


FIG. LVI.

Astigmatic Fan (a chart sometimes used in detecting Astigmatism) as seen by an astigmat, with the worst direction of the eye in the vertical meridian; whilst illustration LVI.

shows the same chart as seen by an astigmatic patient who is ametropic in the horizontal direction.

If, after testing your patient in the ordinary way at the distance letter chart, you are unable to obtain a perfect correction with any spherical lenses, either convex or concave, you may suspect Astigmatism.

You must not assume, because I mention "convex or concave lenses," that if you cannot obtain satisfactory results with plus lenses, you are entitled to jump at once to the conclusion that concave lenses are required. But you should remember that, as long as the convex lens does not make the vision worse, patient *will not* require minus lenses; although, on the other hand, should the weakest plus lens make vision blurred, you may then turn to the concave with advantage.

In order to ascertain whether your patient is astigmatic, you must find out if he sees lines equally black and distinct in all meridians. If he does not, there is Astigmatism; but if he sees them all equally well (the accommodation being at rest), there is not any present. To diagnose this, you must direct your patient's attention to one of the many Astigmatic Charts on the market. The way to use a few of the most valuable of these will be explained later on.

Before going any further, it is of paramount importance that the reader should know which lines on the Astigmatic Chart indicate the meridians of least and greatest defect. It does not matter which of these directions we find, since either of them will suit our purpose—because, when one is known, the other is easily determined; as we are aware that these two principal meridians are always at right angles, or 90° apart, in Regular Astigmatism.

You naturally enough imagine that the direction where the lines appear best to your patient would indicate the meridian of least Ametropia. Now, if I say that the lines which are seen *blackest and clearest* on the chart indicate the *worst meridian* of the eye, the reader will most probably, to say

the least, think it a peculiar assertion to make. Therefore, in order to explain this paradox, and for the reader to comprehend the reason of it, he must familiarize himself with a few laws respecting the *clear perception of a line on the Retina.*

The clearness of the image of a line focussed on the Retina is dependent upon the distinctness of its margins; if these are clear, the line will be seen distinctly. In order to obtain a perfect image of the line, it is imperative that the rays coming

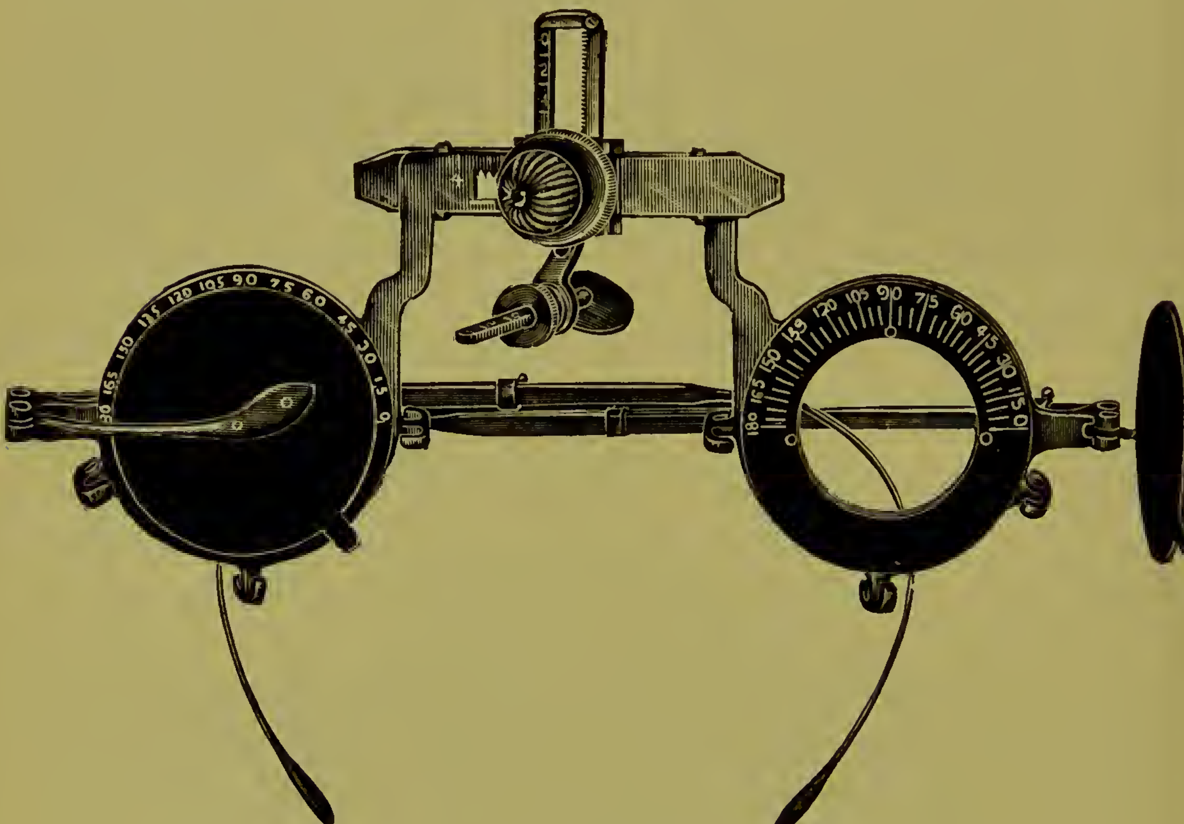


FIG. LVII.

DR. MADDOX'S TRIAL FRAME, Made by Anglo-American Optical Company, London.

from it should be focussed on the Retina, having entered the Cornea at right angles to the axis of the line. If this did not happen, circles of diffusion would be formed, which overlap, and cause the margins to appear blurred. However, if the rays diverge from the line parallel with its axis, the overlapping is only at the extremities of the line; where it is of course made indistinct, but the margins are in no way affected, and therefore

the outline is not interfered with, so the image formed on the Retina is perfectly clear.

Thus it is seen that a patient having Simple Astigmatism, say Hypermetropic in the horizontal and Emmetropic in the vertical, descries (if the accommodation be suspended) horizontal lines distinctly, because the rays coming from the edges of the horizontal line pass through the vertical or normal meridian, while those which emerge from the line parallel with its axis pass through the Hypermetropic meridian; and although focussed imperfectly, overlap each other without interfering with the distinctness of the margins; or, to put it more clearly, for the distinctness of a line we are dependent upon its breadth; and since the breadth of a line is at right angles to the line itself, it follows that a person with Astigmatism in the vertical meridian will see vertical lines clearest, because the breadth of these lines falls upon the horizontal or perfect direction of the eye. Therefore a patient with Astigmatism will see *blackest and best* the lines corresponding to his *worst meridian*, and *most indistinctly* those corresponding to his *least Ametropic* meridian. This, then, explains the following rule:—

The horizontal lines on the chart are seen by the vertical part of the eye; and the vertical lines on the chart by the horizontal portion of the eye; or, in other words the meridian of the eye which corresponds to the dark lines is the meridian of greatest defect.

Example.—If the horizontal lines appear darker than all the others, then it is the horizontal meridian of the eye which is most ametropic; or if the vertical lines are seen darker than the others, then it is the vertical which is the meridian of greatest defect. Or, to express it differently, the series of darkest lines on the Astigmatic Chart represents the meridian of greatest Ametropia.

According to the above, you place the axis of the cylinder in the trial frame, at right angles to the darkest lines on the

chart. The kind of trial frame that must be used when testing for Astigmatism should have two cells, the front one being graduated with a scale showing the various degrees in a half-circle, indicating the several meridians of the eye, so that one can easily turn the cylinder to the desired angle. The best trial frames have the front cell quite distinct from the back one, so that a lens in it may be rotated independently of the other, which greatly facilitates the manipulation of the cylinders. However, this is, of course, a matter for the reader to decide upon himself.

Below is appended a description of the various astigmatic test cards commonly in use:—

"CLOCK FACE."

The first step, when testing for Astigmatism, is to locate the two principal meridians—viz., the meridians of least and

Fig. LVIII.

greatest Ametropia. This is accomplished by ascertaining in which direction patient sees lines blackest. This indicates one of the principal meridians, that of greatest defect; and the other, of course, is at right angles (or 90°) to it, and is the direction in which to place the axis of your cylinder.

The "Clock Face," as in Fig. LVIII., is a chart commonly

used, and is a fair test; the main disadvantage being that all the lines are in view at once, which makes it difficult for the patient to tell you exactly which ones appear darkest to him, especially if he has an active accommodation. Another fault in it is, that the lines are not numbered to correspond with the meridians of the trial frame, it being instead marked like those of a clock face—hence its name.

Well, you direct your patient's attention to this chart, and ask him to tell you which of the lines appear blackest. If they are all alike, there is no Astigmatism present; but should he, for example, see the three lines from IX. to III. perfectly clear and distinct, the others being more or less blurred, those

ASTIGMATIC CHART

Fig. LIX.

from XII. to VI. being the most indistinct, we know that he suffers from Astigmatism in the horizontal; and proceed to test, placing the axis of the cylinder we intend using in the direction of the lines from XII. to VI.

PRAY'S ASTIGMATIC LETTER CHART.

This is another means of diagnosing the defect; but it has the same to be said against it as the "Clock Face" just

mentioned; all the letters being visible at one time. By referring to the illustration, it is seen that this chart consists of various letters of the alphabet, which are constructed of black lines running in several directions to correspond to the different meridians of the eye. This is used in the same way as the "Clock Face"; by finding out which letter appears blackest, one ascertains one of the principal meridians. The Astigmatism is corrected when you place before the eye you are testing such a lens or combination of lenses as make all the letters look equally black.

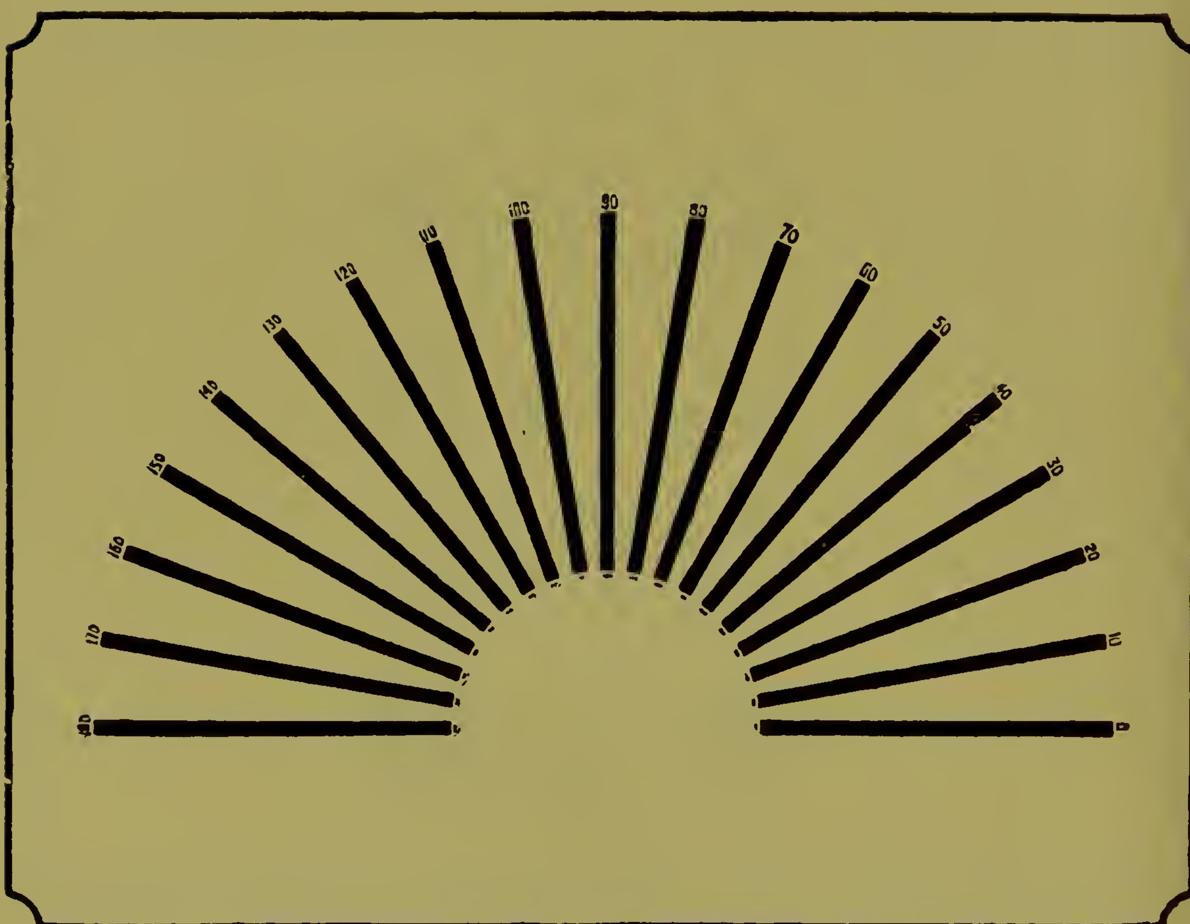


Fig. LX.

THE "FAN TEST," OR "SUNRISE."

This forms an additional chart frequently used. If Astigmatism be present in a case, the lines will not be of equal distinctness; some appearing blacker than others—those

corresponding to the worst part of the eye being the blackest; and the lines gradually becoming more blurred and grey as they approach the opposite meridian (refer to Figs. LV. and LVI.). This chart gives the refractionist a quick method of ascertaining whether there is any Astigmatism present or not, and is employed in the fogging or "paralysing" system of testing; as explained later, in connection with Mixed Astigmatism. But when a patient is found to be astigmatic, I should advise my readers to test with the

ASTIGMATIC DIAL OF THE "G.E.D." TEST CHART.

This is the one I invariably use; and find it the quickest and most accurate, as also the least confusing to the patient of the many test types I am familiar with.

By regarding the illustration you will observe that on either side of the dial are letters of various dimensions. These are for use in ordinary cases of Hypermetropia or Myopia, the value of which was explained earlier—so we need not waste time by repeating here what was then mentioned. The top card of the dial is perforated by two circular openings, through which are seen several black lines. By turning round the second card of the dial you can bring into view lines of various widths, so as to correspond to the size of letters best seen by your patient. The figures seen in a semi-circle above the dial, indicate the number in degrees of the different meridians; and correspond to the markings on the scale of the trial frame in their respective positions; that is, facing each other. When side by side, the figuring of the degrees is necessarily the reverse; those on the chart reading from zero (0) on the left-hand side, and increasing to 180° on the right, and the trial frame being scaled from zero on the right to 180° on the left. It is obvious that with this card, only lines in *one direction* are visible to the patient at once; so that it is comparatively easy for him to locate the exact meridian in which the lines appear blackest to him. In order to test, you rotate the lines

under observation to the horizontal (180°), and slowly turn them around to 180° again; telling your patient meanwhile to stop you when he sees the lines blackest. For instance, if he were to stop you when the lines are at 50°, you know that this represents the worst part of the eye; and therefore place the axis of your cylinder in the trial frame at right angles to this meridian—namely, at 140°. It is as well, after the patient has stopped you at what he thinks is the blackest meridian, to turn the dial 5° or 10° on each side of it, and make sure that

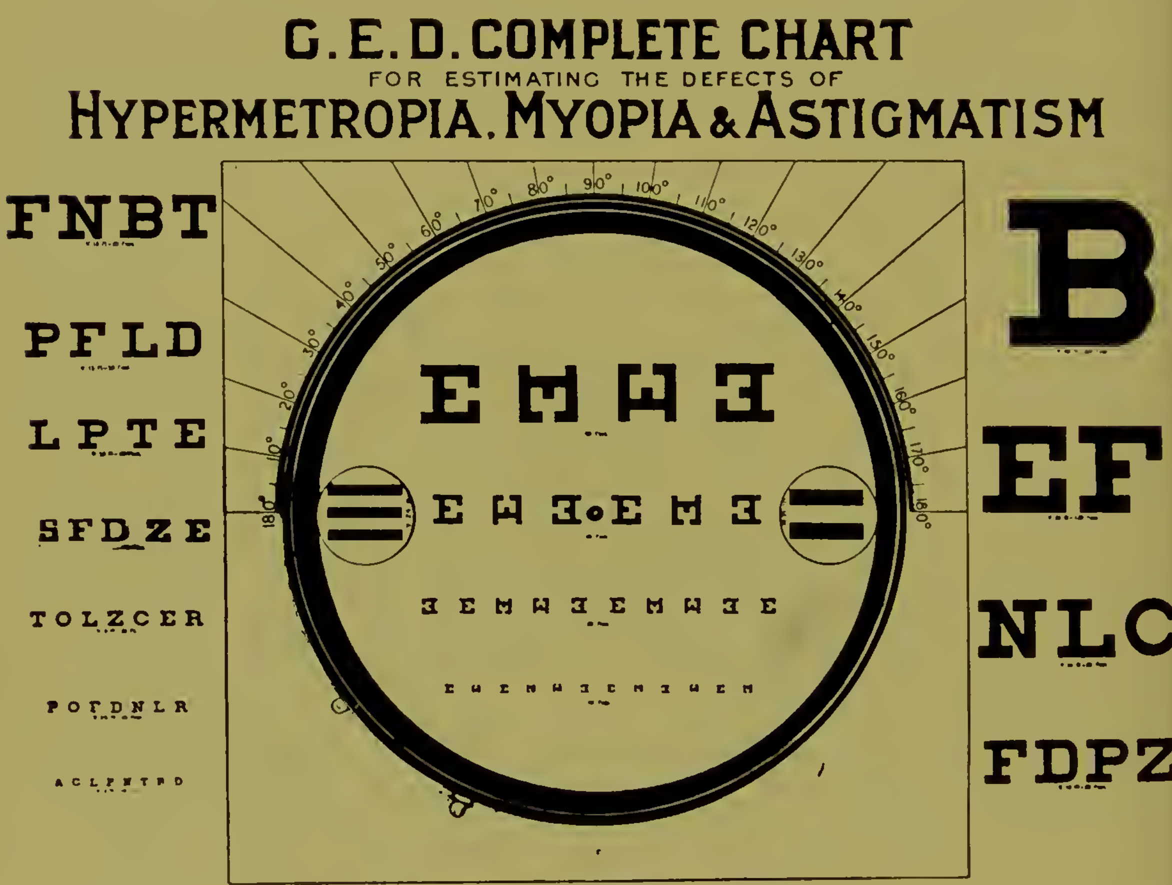


Fig. LXI.

the lines are worse both on the right and left of this position —if they are more blurred on either side, this meridian is correct.

When you wish to compare the worst position with the best, you can rotate the dial from one meridian to the other at once, and when the Astigmatism is corrected, you direct your

patient's attention to the letters on the side again, to see whether the acuity of vision is normal.

It is often found that many patients, after having the right eye tested, when we come to the same letters again with the left eye, remember them, and therefore imagine they see them correctly; which is always misleading to the operator. This great inconvenience is obviated by this chart; as there is a reserve series of letters corresponding in size to those on the sides of the dial; which, although out of sight, can be brought into view at will. And by this means you can immediately confirm your previous correction.

The face of the outer disc in the centre of the chart contains a series of various sized "E's," corresponding to the Snellen's letters at each side, placed in different directions. This forms an excellent chart for children or illiterates; as they are asked to state the position in which the "E's" are placed. This test is simplified by giving the patient a cardboard or metal model E, so that it can be held in the direction of the E you point to in testing. The disc containing these figures can be turned round, so that the patient cannot read their position by rote.

On the reverse side of the chart is the "Fan Test," as an additional card for Astigmatism, in the event of its being required.

This is the chart I refer to, when explaining the routine of testing.

The following few rules should be committed to memory:—

1. When testing for Astigmatism, you should *always* do your utmost to improve vision with spherical lenses first, before going to cylinders.

2. If, in beginning the test for Astigmatism, the spherical lens is 1D. or less (either convex or concave, as the case may be), you can discard it for the time, and use only cylinders. But should the best spherical lens accepted be stronger than this, place it in the back cell of the trial frame, and then continue the test as usual. Be careful, particularly if your

sphere is minus, that it is the *weakest* which gives best visual acuity. In all cases you know this is important, but it is even more so when the eye you are testing is astigmatic; as a too powerful concave sphere can invoke the accommodation, which may disguise the Astigmatism, especially when it is of low degree.

3. Cylinders should not be used until you know where to place the axis; therefore, the first thing to do is, to go to the dial and ascertain this direction.

4. Generally you use the same kind (not strength) of cylinder as the best spherical lens, whether this lens be discarded or not. That is, if a + 3·5 sphere gave best results you could obtain, then if cylinders are necessary, you would try convex ones. Or if the best sphere was − 0·75D., although temporarily discarded, you would use a minus cylinder. In the event of the same kind of cylinder as your sphere making the Astigmatism worse, then you would, of course, try one of the opposite power; and if this was what was required, you would probably have a case of mixed Astigmatism to deal with.

5. But supposing both convex and concave spheres make vision worse, then you always begin with *convex cylinders*, following the same rule as when using spherical lenses.

6. When the meridian of blackest lines is ascertained, and you require to know where to place the axis of the cylinder in the trial frame, use this rule:—

Add 90 if the meridian of blackest lines is 90° or less; and deduct 90 if it is more than 90°.

RATIONALE OF TESTING.

After having seated your patient at the proper distance from the chart, adjusted the trial frame accurately, placed blank disc in front of left eye, and found his acuity of vision, as in testing of the other defects, you hold before the eye you are testing a weak convex lens (+ 0·50 or + 1D., according to the amount of the error), to ascertain whether the patient is hyper-

metropic or myopic. If he rejects the weakest plus lens, you know he is not hypermetropic, but is probably short-sighted, and you therefore try concave lenses. If a weak minus lens improves the vision slightly, and when you place a stronger one in front of the eye (say $-$ 1·50) it is worse, you suspect the presence of Astigmatism.

Say, for example, that without any lens, patient sees with the right eye $\frac{6}{12}$ indistinctly, and that with $-$1D. he sees $\frac{6}{12}$ easily, and perhaps a few letters in the nine-metre line, but you cannot improve the vision beyond this with concave lenses; it shows that the $-$ 1D. is the best spherical correction you can obtain. As it is 1D. (or less), according to the rule given you above, you discard it, replacing the lens in the trial case.

Now direct your patient's attention to the Astigmatic Dial, and rotate it slowly from 180° meridian to horizontal again; instructing your patient to follow the lines, and stop you where he sees them blackest. If they appear darker in one meridian than in another, it shows Astigmatism.

You now place a weak concave cylinder (please note, this is the same kind as the best sphere, which was $-$ 1D.), say $-$0·50D., in the front cell of the trial frame, placing the axis in the direction of the meridian in which the lines appear *most indistinct.* In this case let us imagine he sees the vertical lines best; you, therefore, place the axis of your cylinder in the horizontal. Now return to the dial, leaving the cylinder in trial frame, and rotate the lines *at once* from the best to the worst meridian (*i.e.*, in this case, from the vertical to the horizontal), so as to allow the patient to compare the two positions, and tell you if they are yet both equally black. If the lines are still more distinct in the vertical than in the horizontal, you must increase your concave cylinder to $-$ 1D., keeping the axis in the horizontal, and continue to increase the strength until both the horizontal and vertical meridians are equally black. At each increase of the power of your cylinder, you must compare the two meridians, by rotating the dial quickly from one to the

other, disregarding the intermediate meridians until these two principal ones are alike. When they are, you have corrected the Astigmatism; and it will be found that, by turning the lines to any direction, they will appear of equal blackness. Ask your patient now to look at the letters on the side again; and if he sees $\frac{6}{6}$, you prescribe (in this case) the plain cylinder; but should he not be able to do so, you must add to or deduct from the strength of the sphere until he can.

In this example, there being no sphere at all, you must place in the back cell of the trial frame a weak concave or convex sphere, as the case may require, until you find one that enables the patient to see $\frac{6}{6}$, and this lens would be added to the cylinder.

For example, if the cylinder was -2D., axis horizontal, and it was necessary to add $-0{\cdot}75$ sphere, in order to make the patient read $\frac{6}{6}$, the prescription would read as follows:—

$$-\ 0{\cdot}75 \text{ sph.} \bigcirc -\ 2 \text{ cyl. ax. H.}$$

You must then test the left eye in the same manner. Had the spherical lens that gave best vision in the above case been $-3{\cdot}25$ (or any number above 1), it would have been placed in the back cell of the trial frame, before referring patient's attention to the astigmatic chart; and so your test for the cylinder would have been made through this sphere. On comparing the visual acuity, after obtaining the cylinder, if you are able to reduce the spherical, without making the sight worse, it is well to do so when it is concave; but when it is convex, try to increase its strength.

RULE.

If, after increasing your cylinder, on comparing the two principal meridians, you find that the one that was *previously* the *blackest* is *now* the *most indistinct*, it shows that your cylinder is too strong, and that you have over-corrected the Astigmatism; the effect being, to reverse the two principal meridians.

Always bear in mind that it is not possible in every case to bring patient's acuity of vision up to $\frac{6}{6}$; in which case you must increase the vision as well as you can—although, in the majority of cases, when the defect has not been allowed to go too far, a vision of $\frac{6}{6}$ or nearly so is attainable.

In order to avoid prescribing a concave lens that is too strong, when using minus spheres, a good plan is to ask whether the lens now before the eye makes the letters appear smaller than with the previous lens used. If it does, the lens is too powerful, and a weaker one should be chosen.

If, on referring to the Astigmatic Chart, the patient is undecided as to which of two lines *at right angles* to each other is the blacker, the *spherical* power is wrong—if convex it requires increasing, and if concave, reducing. When testing with cylinders, always so place the axis that, should there be a remaining difference between the appearance of the lines, that which was originally blackest is still the most distinct. If this is not so, you have wrongly ascertained the position of the defect, and must refer again to the astigmatic chart to find the direction of the cylindrical axis.

For reading or close work, in young astigmats, it is usually found that the same lens as for distance will do; but if it does not, you must add to or deduct from the sphere as much as is necessary for comfortable reading. If it is hypermetropic astigmatism, you *increase* the strength of the spherical lens; and in myopic astigmatism you *decrease* the power of the sphere—the same rules holding good as in cases of simple Hypermetropia and Myopia for reading.

RULE.

Never alter the cylinder after once obtaining the proper one to correct the Astigmatism. The same cylinder will do for all distances, and will not, if once accurately found, require any alteration.

There is always a tendency with beginners (and, unfortunately, with others) to prescribe weak cylinders, even if they are not really necessary. In order to avoid this common error, every refractionist should remember that, if a weak cylinder seems to be wanted, and he rotates the axis to right angles to the meridian in which it should be placed, and vision is *not* decidedly impaired, the cylinder is unnecessary. It must *not* be understood from this, that weak cylinders are not to be prescribed; as very often it is the low degrees of defect that produce the most distressing symptoms of Asthenopia (painful

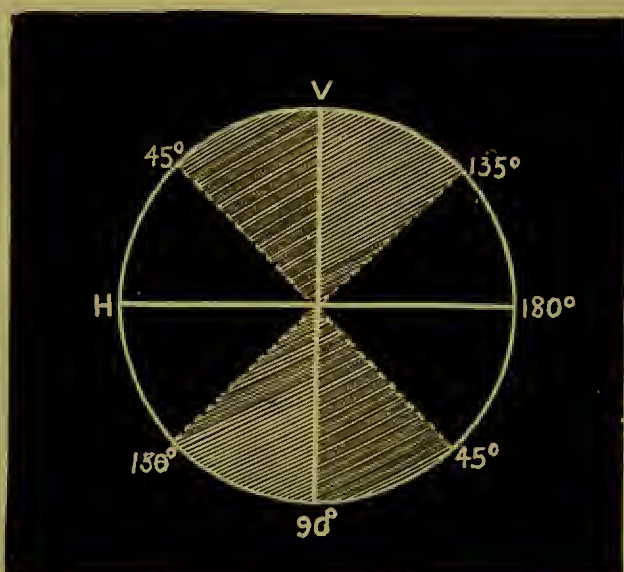


FIG. LXII.

Astigmatism "with the rule" Shaded section represents the myopic direction of the eye, and the black portion within the circle shows the hypermetropic meridians.

vision)—because, in these slight errors the eye exerts itself to overcome its irregularity; whereas, in the higher degrees such an effort would be futile, and the eye abandons the attempt, and so avoids Asthenopia.

As in Hypermetropia and Myopia, after testing each eye separately, you must test binocular vision, and generally it will be found that when the eyes are brought into play together, it is possible to increase the correction of Hypermetropic Astigmatism, and to weaken it if Myopic Astigmatism. As the *cylinder is never altered*, you must increase or decrease

the spherical part of the correction. This is accomplished by holding before the eyes, say + 0·50 sphere in either case, and increase as much as possible without impairing the vision. In Hypermetropic Astigmatism the plus sphere adds to the correction; and in Myopic Astigmatism the plus sphere lessens it. This method will be found a quicker way than altering the spherical lens in the back cell of the trial frame by removing the old one and replacing it by another; and also more comfortable for your patient. The alteration can be noted on paper.

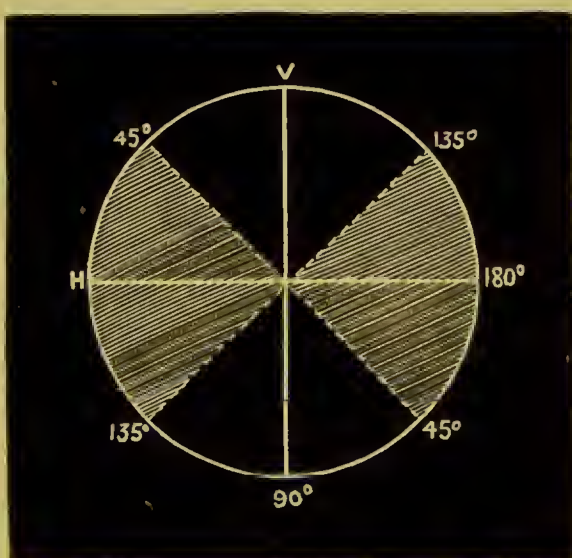


FIG. LXIII.

Astigmatism "against the rule." Shaded portion shows Myopia, and the black indicates Hypermetropia.

In cases of Anisometropia, it is best to give your patient only spherical lenses, to be worn for a short time before prescribing the cylindrical correction. Especially when the axes of the cylinders are oblique, you should be prepared for your patient to complain of discomfort at first; so that, when necessary, you can prescribe the equivalent sphere for a week or so. It must be borne in mind that, if an error of refraction has been neglected for many years (as is only too frequently the case), the peculiar habits of vision existing under such abnormal conditions have become almost "second nature,"

and cannot be easily changed. This accounts for the unsatisfactory results often experienced in prescribing a correction for a person who has not previously been wearing glasses, or who has had some which only imperfectly neutralized the defect, whether it be Astigmatism, Hypermetropia, or Myopia.

The peculiar effect of a cylindrical correction when first worn, is due to the fact that the balance of the retinal images is maintained largely by the oblique muscles; and in Astigmatism, these are in a condition of continual effort, in the endeavour to minimise the imperfect definition due to this defect, so that to some extent this action on the part of the obliques becomes chronic.

When cylinders are first given to correct the Astigmatism, the obliques, from habit, do not relax; so that now their action, instead of improving the condition, tends to counteract the beneficial effect of the correcting cylinders. After a short time, however, if the wearing of the glasses is persevered with, the obliques relax, when the disagreeable symptoms will disappear.

For the sake of convenience, Astigmatism is spoken of as being "with the rule," or "against the rule."

It is "with the rule" when the Hypermetropia (if any) is in the horizontal meridian, or within 45° of it; and the Myopia (if any) is in the vertical meridian, or within 45° of it. When the reverse is the case, it is termed "Astigmatism against the rule" (see Figs. LXII. and LXIII.).

The student should comprehend the meaning of these two terms; as when studying the manipulation of the Ophthalmometer (to be described later), it will be important. To express the meaning differently, Astigmatism with the rule is, when the axis of the plus cylinder is in the vertical meridian, or nearer to the vertical than to the horizontal; and when the axis of the concave cylinder is in the horizontal, or nearer to this meridian than to the vertical. And Astigmatism against the rule is, when the convex cylinder has its axis

nearer the horizontal than the vertical; and the minus cylinder has its axis nearer the vertical than the horizontal.

The personal experience of the writer shows that, in the great majority of cases, the axis of the correcting cylinder in Hypermetropic Astigmatism (both simple and compound) is to be found in the vertical meridian, or within 20° on either side of it; and that in Myopic Astigmatism (simple and compound) it is horizontal, or within 20° of the horizontal. This knowledge will be very useful, as it facilitates testing; for, having ascertained the spherical error, should patient's reading of the distance chart indicate a probable astigmatic complication, a cylinder can be placed in front of the sphere, with its axis carefully adjusted according to the above-stated limits, and its power increased until vision is brought up to the standard. Although this method may seem "rough and ready," and is not to be regularly employed, the reader will find, on increasing experience, how useful a procedure it is under certain conditions; for instance, when through stupidity of the patient, or other reasons, there is a difficulty in ascertaining the direction of distinct vision with the radiating lines.

In writing out your prescription, you copy exactly what you find in your trial frame; and if you test in the way recommended in this chapter, you will find that the correction will be in the best and lightest form, and will require no transposing.

The "paralysing" system of testing is valuable in many cases of Astigmatism, particularly in the Mixed variety; and the following will give an indication of its application:—

Testing one eye at a time, tell patient to look at the Fan lines, as on the back of the G.E.D. complete chart (Fig. LXI.), which should hang perfectly upright, at about 20 feet away. Now place in the front cell of trial frame a plus sphere of sufficient power to entirely blur all the lines; and keeping this before the eye, gradually reduce its effect by holding minus

spherical lenses in front of it, until *one line* shows up quite black and distinct. The difference between the plus and the minus sphere should now be inserted in the back cell of the trial frame, and the strong convex lens removed. Say it is the vertical line which appears black; you now place in the front cell of trial frame a concave cylinder with the axis horizontal, increasing it until all the lines look clear and distinct; when the test will be completed, and on referring to the distance letter chart, vision should be good. If the concave cylinder is weaker than the sphere, it is a case of Hypermetropic Astigmatism; but if the cylinder is the stronger, then Mixed Astigmatism is indicated.

Before closing this chapter, I will explain the use of the Stenopaic Disc, as an auxiliary method of estimating the direction and the amount of Astigmatism. This disc, as you know, is simply made of rubber, with a narrow slit across the centre. Do not use it as a means of testing for Astigmatism, unless you require to verify your correction found with the trial lenses; or if you find a difficulty in estimating the defect with cylinders and astigmatic chart.

You commence the test in the usual way—viz., by placing patient at six metres from the test types, adjusting trial frame, and putting blank disc before left eye, etc. After which you place in the front cell of trial frame the Stenopaic Slit, and slowly rotate it until patient tells you to stop where he sees clearest. You instruct him to look at the ordinary letter type, *not* the dial. If he sees best with the slit in the horizontal, this is the meridian of least defect, and consequently the position for the axis of the cylinder. Having found this direction, turn to the Fan Chart, discarding the Stenopaic Disc, and use the necessary kind of cylinder (*i.e.*, + or −) with the axis placed in the meridian indicated by the slit; increasing the strength until the lines are all equally black. However, if you prefer testing entirely with this disc, without using cylinders, after finding the direction of least defect, you place

in the back cell of the trial frame (behind the disc), a weak convex lens, to find out if this meridian (the horizontal) is hypermetropic or myopic. If the former, you prescribe the strongest convex lens placed behind the Stenopaic Disc that affords the best vision. Say, for example, this is + 2, you write down + 2D. H. Now turn the slit to right angles (viz., the vertical), and ascertain by placing lenses in the back cell of the frame whether this direction is hypermetropic or not. If it is myopic, you give the weakest concave lens behind the disc that affords the best vision. Let us suppose this is −3D., when you would write −3D. V. The correction then for this eye would be:—

$$\frac{+2\text{D. Hor.}}{-3\text{D. Vert.}}$$

This example is a case of mixed Astigmatism "with the rule."

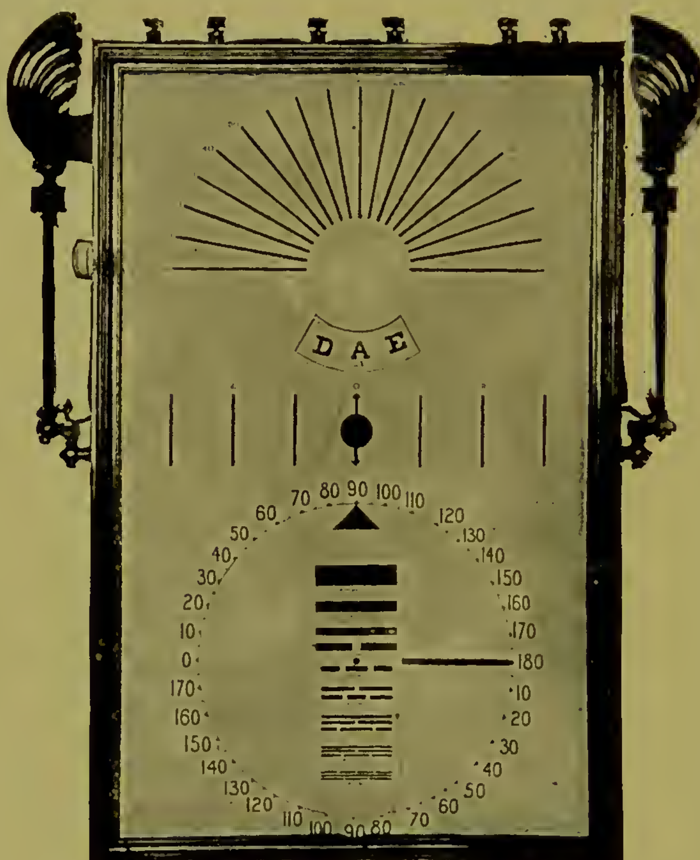
The above prescription should be transposed into a sphero-cylindrical form; as will be explained in the next chapter, on "Transposing."

The Combination Testing Cabinet illustrated here will appeal to all refractionists, owing to the ease and rapidity with which the subjective examination can be conducted with it. As will be seen from the accompanying photograph, it comprises all the charts necessary for testing, including the muscle test. The Snellen's type (as shown D A E) can be changed at will, from the operator's end of the room; the letters varying from the 200-ft. size down to the smallest, and their arrangement being such that they can be changed without the patient's knowledge—which renders guessing on their part almost impossible.

The Astigmatic Charts consist of the familiar "Fan" or "Sunrise," and also one of new design, which can be rotated (without leaving the patient's side) to any desired meridian, and the axis of the correcting cylinder is indicated mechanically, without calculation. For Astigmatism, the Fan test at

the top is first employed, to ascertain the blackest line; when the astigmatic bar should be rotated until its pointed end (this is really a *red* pointer, although not so shown in the illustration) is in the direction of the line most distinctly seen, as shown by the Fan—when this is done, the long black pointer will indicate the direction for the axis of the correcting cylinder.

Since the short lines on the bar run in the direction of



"G.E.D." Combination Testing Cabinet.[1]

Fig. LXIV.

the meridian of *worst vision*, when the cylinder is placed before the eye its effect is immediately apparent; and as each successive cylinder is used, so the lines on the bar are seen more and more distinctly. That cylinder which enables patient to see clearly the lines which should be seen at the

[1] Made only by Anglo-American Optical Co., London.

distance at which he is seated, will be the correction; and if the attention be then turned to the Fan lines again, they will all appear equally clear.

It may sometimes be found that a person cannot indicate from the Fan test, which lines look darkest, particularly in oblique directions. In such cases, the astigmatic bar can be used alone, by rotating it slowly through the various meridians, noting the direction of the black pointer; the meridian where the bar is seen clearest gives the direction of greatest error. Having found this direction, *turn the bar to right angles*, leaving it there, where it will be seen indistinctly; and now use cylinders (*axis according to black pointer in its present position*), increasing their power until the whole of the bar is seen well, as mentioned above, in describing the other method of testing.

The astigmatic bar, if placed horizontally, with the black pointer downwards, forms quite an efficient illiterate test; patient being told to count the lines on this bar, from right to left, until such a lens is found as enables him to make out exactly the lines which should be seen at the distance at which he is seated. It will be noticed that the smaller lines are broken, with the idea of making a rather finer test; as the patient should be able to count the number of breaks in these lines, when vision is rendered normal.

For Muscle Testing, the small electric light in the centre is the "object"; the degree of muscular insufficiency being easily read off the scale on each side.

CHAPTER IX.

TRANSPOSING.

Transposing is altering a prescription from one writing to another of different and generally better form. This does not alter the refractive power of the combination, but merely changes the curvature; so that it matters not which formula is used, because the result is the same to the patient, as he sees equally well with either combination. But probably in one case the glasses would be heavy, and in the other lighter; and would give less work to the optician who grinds your lenses.

In retinoscopy and other objective tests, transposing is also necessary; as well as in using the Stenopaic Slit in testing for Astigmatism. One may have to transpose a prescription of three separate kinds, each necessitating different methods of working out, although the rules for one may also hold good for the other. In order to make it more simple for the beginner, we will discuss them each in turn, giving their separate rules as concisely as possible.

Let us first take for consideration this prescription:—

$$+ 1 \text{ sph.} \bigcirc + 1 \text{ cyl. ax. } 90^\circ$$

In transposing any combination, we only take into account the two principal meridians; that is, the meridian in which the axis of the cylinder is placed, and the meridian at right angles to it; or in other words, the meridians of least and greatest Ametropia.

In analysing this prescription, we must remember:—

1. That "90°" in the prescription indicates the meridian in which the axis of the cylinder is placed; and that in this direction the cylinder has no focal power or strength.

2. That a spherical lens is equally curved in all directions; consequently its power is equally distributed in both the principal meridians.

3. That a cylindrical lens has power only in the meridian at right angles to the direction of its axis; consequently, if the axis is placed, say, vertical, the strength or curve of the cylinder is in the horizontal. (Strictly speaking, of course, the cylinder has power in all meridians *excepting* in the direction of the axis; but for our purpose in transposing, it will be best for the reader to consider it as above stated.)

4. A prescription is written incorrectly (*i.e.*, not in the best form) if the signs of the sphere and the cylinder differ, unless the cylinder is at least twice the power of the sphere.

The prescription given above is written correctly, as the sphere and cylinder do not differ in sign; therefore there is no necessity for us to endeavour to improve it—but we will find out what the patient is suffering from, who requires this correction to improve his vision.

In order to ascertain this, we for convenience draw a diagram thus:—

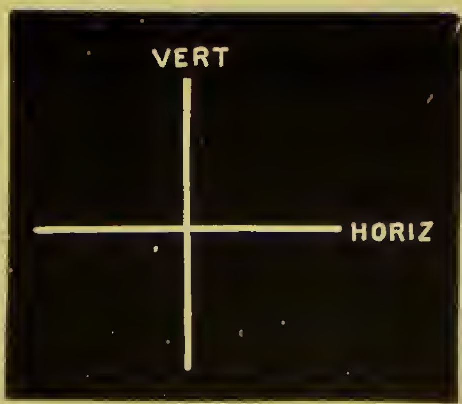


Fig. LXV.

showing the two principal meridians. Bearing Rule 2 in

mind, we know that the power of the spherical lens is in both directions; that is, + 1 in the vertical and the horizontal meridians. And since the cylinder is placed axis vertical in our prescription, the strength or curve of it is in the horizontal (see Rule 3 above).

This makes our diagram of the two principal meridians of this eye represented like this:—

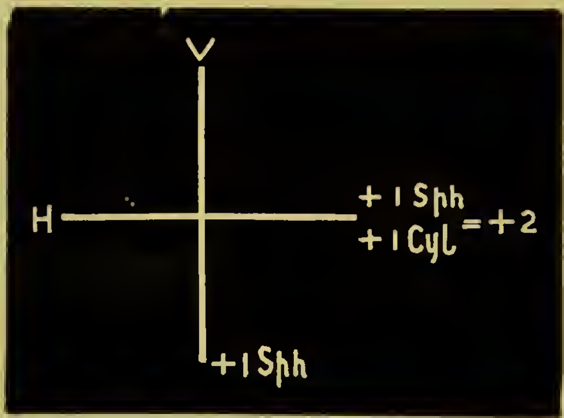


FIG. LXVI.

that is, + 1 in the vertical meridian, and + 2 in the horizontal. This patient, then, suffers from Hypermetropia in both directions, but more so in one meridian than another—in other words, from Compound Hypermetropic Astigmatism.

To take another example—

+ 2·00 sph. ⊃ + 1·50 cyl. ax. 45°.

According to our Rule 4, this prescription is written accurately. Let us now draw the diagram, placing the spherical power in both meridians, and the cylindrical power at right angles to its axis—

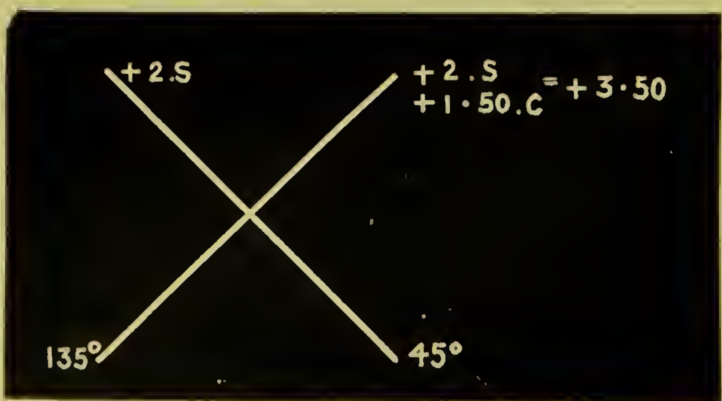


FIG. LXVII.

and we have + 2 in the 45° meridian, and + 3·50 in the 135°; which is a case of Compound Hypermetropic Astigmatism.

Example III.:—

— 1·25 sph. ⁀ — 0·50 cyl. ax. 180°.

The curve of the spherical lens is placed in the *horizontal and vertical* meridians; but the cylindrical power is only in the *vertical* (*i.e.*, at right angles to the axis), which makes diagram—

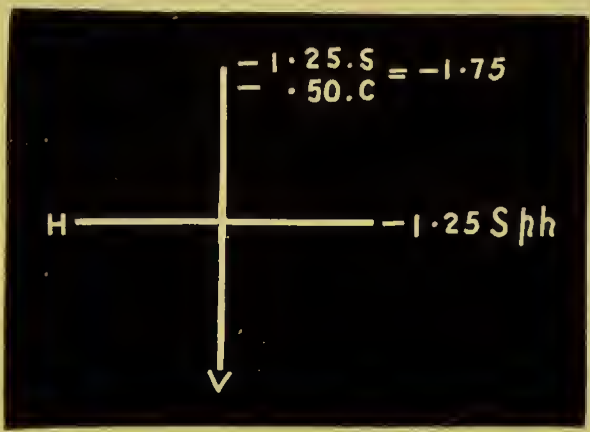


Fig. LXVIII.

This is a case of Compound Myopic Astigmatism, — 1·75 in the vertical, and — 1·25 in the horizontal; the prescription for which was accurately written.

Another example—

— 3·00 cyl. ax. 50°.

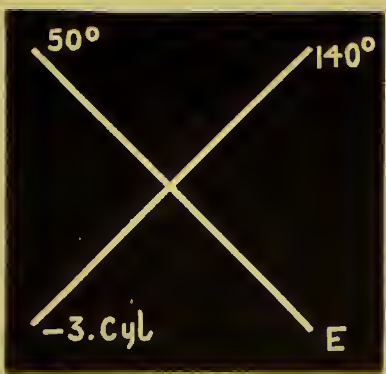


Fig. LXIX.

This patient is emmetropic in one meridian, and myopic in the other, showing Simple Myopic Astigmatism. The above diagram was obtained by following Rule 3: *i.e.*, placing the power of the cylinder in the meridian at right angles to the direction of its axis.

Now, if the reader has any prescription, provided it is written accurately, and he wishes to know what his patient suffers from, he has simply to draw a diagram representing the two principal meridians; placing the power of the sphere in both directions, and the strength of the cylinder in the meridian at right angles to its axis. It is not *necessary* to write "sph." and "cyl." against the powers in the diagram you draw; I only do it so as to make it clear for the reader to understand how I obtain the different results in each meridian.

If you have followed the above rules and examples carefully, you should now be able to transpose any similar prescription without much difficulty.

We next come to the second transposition you may have to make. Instead of showing what defect a patient has, from his prescription, you must now write out a prescription, when you know the strength of lens required to correct the two principal meridians separately. It is obvious that this procedure must be the reverse of that just explained.

As an example, we will take a case in point; namely, the correction found with the Stenopaic Disc, in the last chapter on Astigmatism, which was, if you remember:—

$$\frac{+\,2\,\text{H.}}{-\,3\,\text{V.}}$$

This represents the defect present in the horizontal and vertical meridians; and is not a prescription, in the proper sense of the term, but only shows what the kind and amount of error is. The "H." and "V." here indicate *the direction in which the defect is;* whereas, if the word "axis" were

before the "H." or "V.," it would show that the defect was at right angles to the meridian indicated—the word "axis" (in this instance) meaning "at right angles to."

It is our intention to give lenses to correct the above; and in addition to the previous four rules, we must also observe another:—

5. Always to correct the meridian of least defect first, with a spherical lens; allowing for its effect on the meridian at right angles to it, which you correct with a cylinder, placing the axis in the meridian first corrected.

The first step in this calculation is, to draw our diagram, placing the + 2 in the horizontal, and − 3 in the vertical meridian. We now work out our prescription from this:—

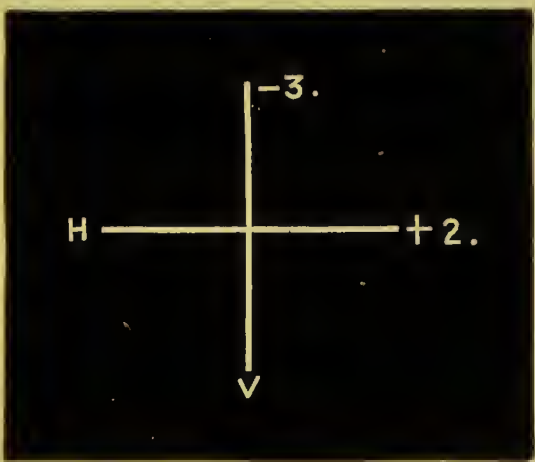


FIG. LXX.

According to the new rule (5), we correct the meridian of least defect first, with a sphere; allowing for its effect on the other meridian. The horizontal is the meridian for us to correct, which we do with a + 2 sphere, making it emmetropic; but it is obvious that, since the vertical meridian is myopic, placing a + 2D. lens before it, must necessarily make this meridian worse. This *is* the case; and the effect of the + 2 sphere, to put it graphically, is:—

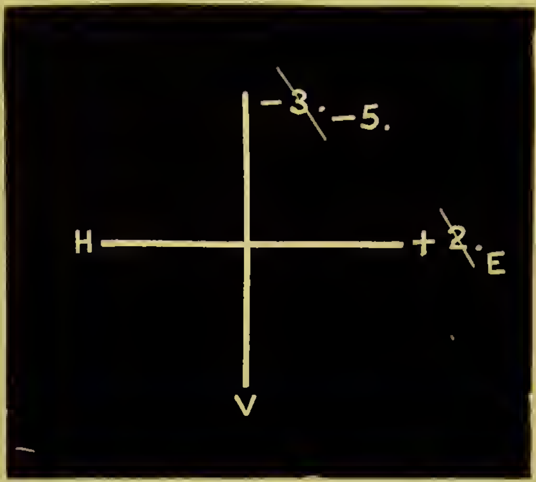


Fig. LXXI.

There now remains to be corrected only the vertical meridian, the horizontal being emmetropic. This is accomplished by a − 5D. cylinder, axis in the horizontal, which was the meridian first corrected. (Please refer to Rule 5, and you will see that we have in this example followed it out exactly.) Our prescription for this case is :—

$$+ 2 \text{ sph.} \bigcirc - 5 \text{ cyl. ax. H.}$$

Example VI. :—

$$\frac{+ 1{\cdot}75 \text{ H.}}{+ 1{\cdot}00 \text{ V.}}$$

This transposition is somewhat less complicated than the last one, on account of the defect being the same, instead of different, in both meridians. Draw the diagram representing the defect in each principal meridian ; and we have :—

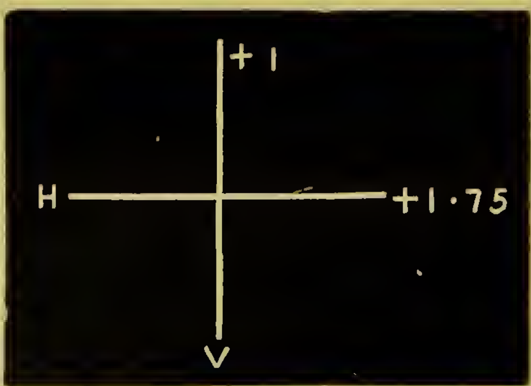


Fig. LXXII.

Following Rule 5, we correct the vertical meridian first with a + 1 sphere. The effect of this is to exactly neutralize the error in this meridian, and to partly correct that in the horizontal; leaving + 0·75 still to be corrected with a cylinder, the axis of which is of course placed in the meridian which has already been corrected.

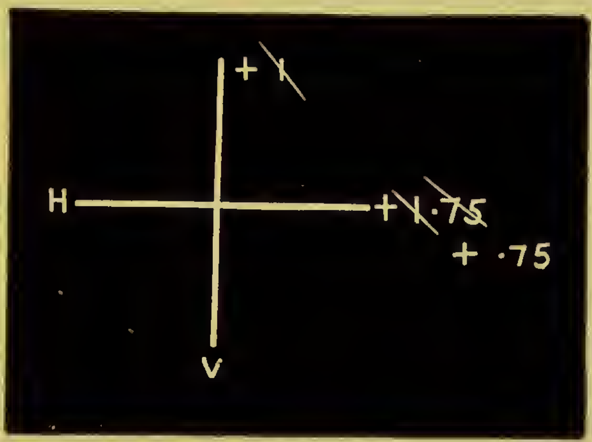


Fig. LXXIII.

Our prescription then reads :—

+ 1 sph. $\bigcirc$ + 0·75 cyl. ax. V.

Example VII. :—

$$\frac{-\ 1{\cdot}00\ \text{H.}}{-\ 1{\cdot}00\ \text{V.}}$$

This is, graphically :—

Fig. LXXIV.

and shows a case of Simple Myopia; and as both the meridians require -1 to correct them, the prescription is:—

$$-\ 1\text{D. sph.}$$

Example VIII.:—

$$\frac{+\ 1{\cdot}75\ \text{H.}}{\text{Emm. V.}}$$

From the diagram, it is seen that this is a case of Simple Hypermetropic Astigmatism:—

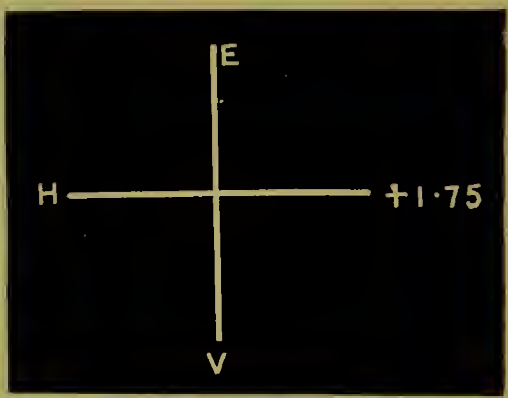


Fig. LXXV.

As there is no correction needed in one of the meridians, this eye is corrected by means of a plain cylinder; the axis being in the emmetropic meridian, so that the curve or power may be in the direction requiring correction. Our prescription reads:—

$$+\ 1{\cdot}75\ \text{cyl. ax. V.}$$

We shall next consider those prescriptions which are inaccurately written. In these cases, we must first of all ascertain what defect the prescription is given to correct; and then, from our own diagram, write out the necessary formula in the proper way. The most important rule in transposing is, to correct the meridian of least defect first with a spherical

lens; and when a prescription is wrongly written, it is through the writer neglecting to follow this rule.

$$+ 1 \text{ sph.} \supset - 0{\cdot}50 \text{ cyl. ax. V.}$$

By drawing our diagram, and placing the power of the sphere in both meridians, and that of the cylinder in the meridian at right angles to the axis (according to Rules 2 and 3), we obtain :—

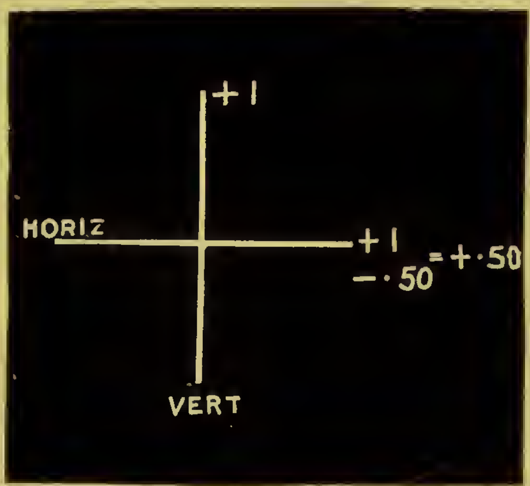


Fig. LXXVI.

By taking the meridian of least defect as the spherical lens (viz., the + 0·50), we obtain :—

Fig. LXXVII.

This is arrived at by the + 0·50 spherical lens fully correcting the horizontal meridian, and partially correcting the vertical, where there now remains to be corrected, + 0·50. This is corrected by a + 0·50 cylinder, axis in the horizontal, or now emmetropic, meridian; the prescription being:—

+ 0·50 sph. ⁀ + 0·50 cyl. ax. H.

Another example:—

+ 1·50 sph. ⁀ − 1·50 cyl. ax. H.

By drawing the diagram, and following Rules 2 and 3, we obtain:—

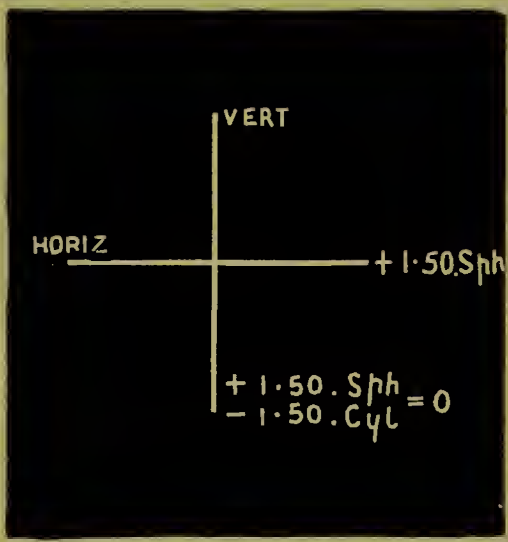


Fig. LXXVIII.

The result in the vertical meridian is, of course, obtained by the + 1·50 sphere neutralizing the − 1·50 cylinder; showing only + 1·50 to be corrected in the horizontal, the vertical meridian being emmetropic. It is a case of Simple Hypermetropic Astigmatism "with the rule," and is corrected by:—

+ 1·50 cyl. ax. V.

If the reader will compare this prescription with the one in the example, he will then see the necessity for the refractionist to have a knowledge of transposing. This is a

case in point, in which not only is the correct prescription lighter and thinner than the other, but there is also a saving in price of nearly fifty per cent.—a considerable amount.

Example XI.:

$$-3 \text{ sph.} \bigcirc + 1 \text{ cyl. ax. } 45°.$$

By the rules followed in the last example, our diagram is again drawn thus:—

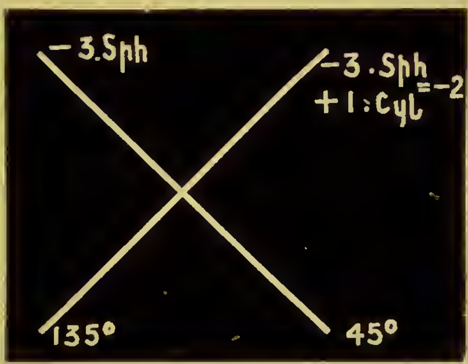


Fig. LXXIX.

The −2 in the 135° meridian is obtained by adding the positive quantity to the negative, which, being identical to subtracting one from three, equals two (which is the same, only in other words, as was explained in the last example). The meridian of least defect is 135°, consequently we make −2 our sphere, which reduces the condition to this:—

Fig. LXXX.

The prescription for this example is completed with a -1 cylinder, axis 135°; and reads as follows:—

$$-2 \text{ sph.} \bigcirc -1 \text{ cyl. ax. } 135°.$$

We will now take a few examples of Mixed Astigmatism for transposing. These involve nearly all the rules given during the chapter, and will be an interesting form of recapitulation.

$$+1 \text{ sph.} \bigcirc -2 \text{ cyl. ax. H.}$$

This prescription, although the signs of the sphere and cylinder are not the same, is accurately written. If the reader remembers Rule 4, he will know this, as it says: "A prescription is written incorrectly, if the signs of the sphere and the cylinder differ, *unless* the cylinder is at least twice the power of the sphere." Well, in this case it *is* double the number of the spherical lens; therefore we cannot improve the writing of the prescription. But there are two other methods of expressing the same correction; so that to work this out, we will again refer to our diagram, showing what the defect is in this case. The sphere is placed in both meridians, and the cylinder only in the vertical, making:—

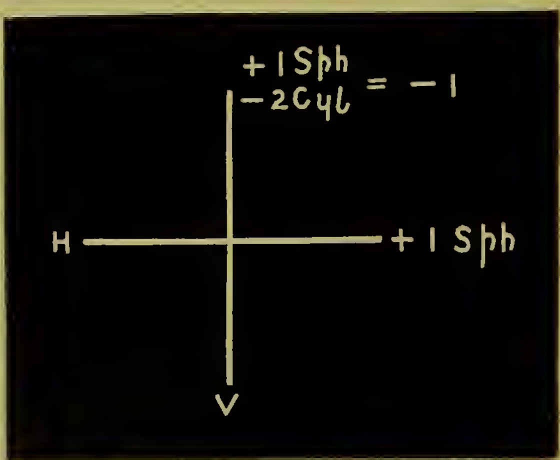


Fig. LXXXI.

which shows a case of Mixed Astigmatism, myopic in the

vertical, and hypermetropic in the horizontal. In the example given, the horizontal meridian was taken as the sphere; so we will make a difference by taking the vertical. The −1 sphere fully corrects this meridian, but makes the horizontal 1D. more defective, because that direction is hypermetropic, and is naturally made worse with a minus lens. So we must allow for this by giving a + 2 cylinder, axis vertical; and our prescription will read:—

$$-1 \text{ sph.} \bigcirc +2 \text{ cyl. ax. V.}$$

The third way of transposing this is by means of crossed cylinders, which, if you remember, in practice you never prescribe. By making the cross lines we found out that the defect to be corrected was:—

$$\frac{+1 \text{ H.}}{-1 \text{ V.}}$$

We first take the horizontal, and correct that with a + 1 cylinder, axis vertical. This does the needful in the horizontal, without altering the vertical meridian. The vertical is corrected with a − 1 cylinder, axis horizontal; which does not interfere with the 180° (Hor.) meridian, as the axis of the cylinder is practically plane glass. Thus we obtain our prescription:—

$$+1 \text{ cyl. ax. V.} \bigcirc -1 \text{ cyl. ax. H.}$$

The above should explain the statement which I made earlier, to the effect that "Sphero-cylinders are cross cylinders in effect."

Another example of Mixed Astigmatism:—

$$\frac{+2{\cdot}50 \text{ H.}}{-1{\cdot}75 \text{ V.}}$$

or its equivalent—

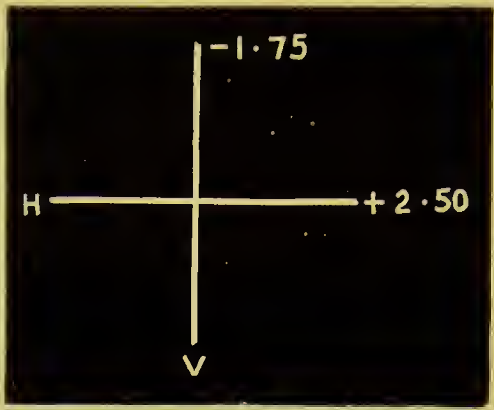


Fig. LXXXII.

represents the defect to be prescribed for.

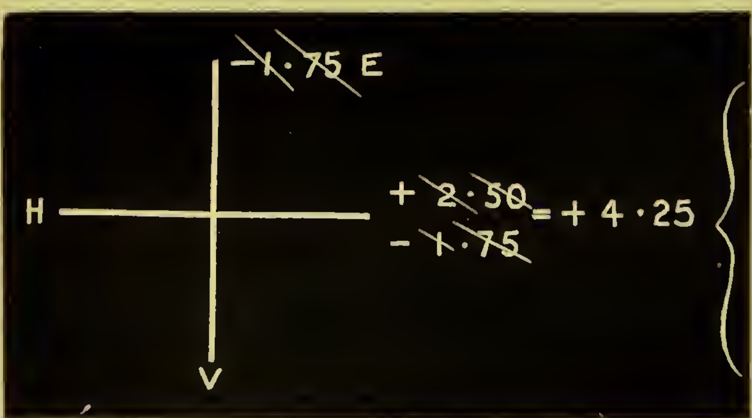
There are three formulæ, all of which would give equal satisfaction to the wearer, as far as vision is concerned.

Let the first form be the cross cylinders. We will correct the vertical with a −1·75 cylinder, axis 180°; so as to render it normal, and not to alter the horizontal meridian. This you neutralize by a +2·50 cylinder, axis 90°, or vertical; and the prescription is written:—

$$-1{\cdot}75 \text{ cyl. ax. H.} \supset + 2{\cdot}50 \text{ cyl. ax. V.}$$

The two next ways of expressing a prescription for the above eye are by combinations of sphero-cylinders.

One is, by taking the meridian of least defect for the sphere, which is −1·75 sphere; leaving only +4·25 to be corrected in the horizontal, by means of a cylinder, axis vertical (see Diagram below)—



This is obtained by placing before the hypermetropic part of the eye a −1·75 lens, which of course makes it worse to this amount.

Fig. LXXXIII.

the prescription reading :—

$$-1{\cdot}75 \text{ sph.} \bigcirc +4{\cdot}25 \text{ cyl. ax. V.}$$

The other and last way is by taking the meridian of greatest defect as the spherical lens. The $+2{\cdot}50$ sphere makes the horizontal normal, and the vertical myopic to the extent of $-4{\cdot}25$; which you correct with a $-4{\cdot}25$ cylinder, axis horizontal, making the prescription :—

$$+2{\cdot}50 \text{ sph.} \bigcirc -4{\cdot}25 \text{ cyl. ax. H.}$$

The second way was the best form in which to have the prescription made up.

Before leaving the subject under discussion, I intend giving two more rules by which the reader, provided he thoroughly follows what has been said in this chapter, and memorises the rules well, should be able to tell at a glance :—

1. Whether the prescription is accurately written or not;
2. What defect the prescription is given to correct;
3. If he knows the defect, the correction to prescribe for it;
4. And lastly, to be able to alter one prescription into another of different form, without resorting to any diagrams whatever.

The first he would see, of course, by the knowledge that if the sphere and cylinder differ in sign, the prescription is wrongly written, unless the cylinder has *twice the power of the sphere.*

The second is acquired by understanding :—

Rule 6. That the power of the sphere is always placed in the direction of the axis of the cylinder; and the sum of the sphere and cylinder is in the opposite meridian to this.

Example XIV. :—

$$+3 \text{ sph.} \bigcirc +1 \text{ cyl. ax. V.}$$

To quote the rule given above, "the power of the sphere is in the direction of the axis of the cylinder"—that is, + 3 vertical; and "the sum of the sphere and cylinder is in the opposite meridian"—namely, + 4 horizontal; the result being:—

$$\frac{+3 \text{ V.}}{+4 \text{ H.}}$$

If the sphere and cylinder are of opposite powers, then adding them together is the same as subtracting one number from the other and prefixing the sign of the *greater* number; for example:—

+ 1	added to	− 1	=	0
+ 4	„ „	+ 2	=	+ 6
− 1	„ „	− 3	=	− 4
+ 3	„ „	− 1	=	+ 2
+ 2	„ „	− 5	=	− 3

(The reader should work Example XIV. out on paper in the other method, using diagram, and see if it is correct.)

So as to be able to give a prescription at once, you must remember:—

Rule 7. The weaker quantity is taken as the spherical lens. And the difference between the two amounts represents the strength of the cylinder; the axis of which is placed in the meridian of least defect.

Example XV. :—

$$\frac{+1 \text{ H.}}{+3 \text{ V.}}$$

Again quoting the rules, "the weaker is the sphere"; that makes + 1 sphere. "The difference between the two meridians represents the strength of the cylinder; the axis

being placed in the meridian of least defect"; equals + 2 cylinder axis on the horizontal. Of course, when you remember these rules, you will at once write down, on seeing what the defect is, this prescription:—

$$+ 1 \text{ sph.} \bigcirc + 2 \text{ cyl. ax. H.}$$

The reader should also try to prove this, and see if it is correct, for himself.

Example XVI.:—

$$\frac{+ 2\cdot25 \text{ H.}}{- 1\cdot50 \text{ V.}}$$

In this example, where the defect is Hypermetropia in one direction and Myopia in the other, Rule 7 is followed; but the difference between the *positive* 2·25 and the *negative* 1·50, is equal to their sum, 3·75; therefore, the prescription reads:—

$$- 1\cdot50 \text{ sph.} \bigcirc + 3\cdot75 \text{ cyl. ax. V.}$$

You notice that the cylinder takes the *sign* of the greater defect.

Another *Example XVII.*:—

$$\frac{+ 1\cdot75 \text{ H.}}{- 3\cdot0 \text{ V.}}$$

By Rule 7 is obtained:—

$$+ 1\cdot75 \text{ sph.} \bigcirc - 4\cdot75 \text{ cyl. ax. H.}$$

So as to be able to alter one prescription into another combination at once, the reader must remember yet two more rules:—

Rule 8. To be followed when the prescription you wish to alter is a sphero-cylinder; as follows:—

(*a*) Add the power of the original sphere to that of the cylinder, to obtain the spherical portion of your new prescription; the sign of it being + or −, according to the result of your addition.

(*b*) The strength of your new cylinder will remain the same as the original one; but it will be of the opposite sign, and the axis will be at right angles to its former direction.

Example XVIII.:—

+ 3 sph. $\bigcirc$ – 2·25 cyl. ax. 70°.

In altering that according to rule (*a*), the sphere equals + 0·75; and following rule (*b*), the cylinder is + 2·25 ax. 160°; making the complete combination:—

+ 0·75 sph. $\bigcirc$ + 2·25 cyl. ax. 160°.

In the case of changing a cross cylindrical combination into a sphero-cylindrical form, the following rule is used:—

Rule 9. (*a*) The sphere has the same power and sign as one of the cylinders.

(*b*) The sign and axis of your new cylinder remain the same as those of the other cylinder in the original prescription. The strength of it equals the sum of the *power* of the first and second cylinders in the original combination.

Example XIX.:—

– 1 cyl. ax. V. $\bigcirc$ + 2 cyl. ax. H.

In this example let us take the first cylinder for our sphere, and we have – 1 sphere. Now our cylinder is convex, and the axis is in the horizontal meridian (see Rule 9 [b]). The strength equals the powers of both cylinders in the original prescription. Then our combination becomes:—

– 1 sph. $\bigcirc$ + 3 cyl. ax. H.

Since either the first or the second cylinder may be taken as the spherical lens, it is obvious that the above prescription could be transposed into two different forms; by taking in one case the first cylinder as your sphere, and in the other the second cylinder.

When the *second* cylinder is taken for the spherical portion of your combination (always giving preference to the weaker one), your new cylindrical lens is the same in kind and axis as the *first* one given in the original "cross" form.

Example XX. :—

$$+ 2{\cdot}75 \text{ cyl. ax. V.} \overset{\frown}{\smile} - 1{\cdot}75 \text{ cyl. ax. H.}$$

Suppose we take the second cylinder as our spherical, we have — 1·75 sphere. Our cylinder will be of the same kind and axis as the first cylinder; but the power equals the sum of the numbers of both cylinders in the original prescription. And our result is as follows :—

$$- 1{\cdot}75 \text{ sph.} \overset{\frown}{\smile} + 4{\cdot}50 \text{ cyl. ax. V.}$$

It is always better to take the weaker of the cross cylinders for the spherical lens; and this you will notice was done in the examples just given.

In practice, all cross cylindrical combinations will be plus *and* minus; but if in examination, or elsewhere a prescription is given in which both cylinders are plus *or* minus, Rule 9 (*b*) should read:—"The sign and axis of your new cylinder remain as those of the other cylinder in the original prescription; but the strength equals the *difference* between the two powers."

Example :—

$$+ 3 \text{ cyl. ax. } 70^\circ \overset{\frown}{\smile} + 5 \text{ cyl. ax. } 160^\circ$$

By Rule 9 (*a*) we obtain + 3·D. as our sphere; and by the altered rule just quoted, our cylinder equals + 2 ax. 160°.

To take a last example :—

$$- 3{\cdot}75 \text{ cyl. ax. } 10^\circ \overset{\frown}{\smile} - 6 \text{ cyl. ax. } 100^\circ.$$

By working according to the rules given, it is transposed into

$$- 3.75 \text{ sph.} \overset{\frown}{\smile} - 2{\cdot}25 \text{ cyl. ax. } 100^\circ.$$

The reader will not grasp exactly how Rules 6, 7, 8 and 9 are arrived at, unless he understands perfectly the transposing with the help of the diagrams. So it is advisable, before attempting this new way, that he should perfectly familiarise himself with the other. To obtain further practice in this, it would be well to try to transpose some imaginary cases; or if you have had any experience already in testing, to

transpose some of your previous corrections—as you cannot do too much of this.

The advantages of a toric lens are, that it can be made more periscopic, thereby giving an enlarged field of vision; and owing to their shape, the distortion frequently apparent with lenses of ordinary curvature is greatly diminished. Also, the deep curve of the toric allows the lens to be placed closer to the eye, which is particularly advantageous to persons having long lashes.

A toric lens has a spherical curvature on one side, and that of two crossed cylinders on the other. In practice, the least curvature of the toric surface is a fixed quantity, and is termed the "base curve." To thoroughly comprehend the meaning of the "base curve" is essential for an understanding of the transposing of these lenses.

A cylindrical surface, we know, is one in which (considering the two principal directions only), the axis is plain glass; the meridian at right angles having a curvature represented by the power of the lens. This is obtained by grinding a cylindrical curve on a flat or plane piece of glass; so that, when the surface is ground, the direction of the axis is left parallel to the opposite side.

In the case of a toric lens however, the cylindrical curve is not ground upon a flat surface, but may be considered as being worked upon one of definite spherical shape; so that when completed, the direction of the axis has the original curvature of this surface, and the opposite meridian has the power of this "base" added to the cylinder ground upon it. Thus, assuming that the base upon which the cylinder was worked is 6D., and that the cylinder itself is say 2D., then the toric surface would have a curvature of 6D. along one direction, and of 8D. at right angles to that—the cylindrical element being 2D.; that is, the difference between the two directions. The 6D. would be termed the "base curve," which is the meridian of least curvature of the toric surface.

It is obvious from this, that if the base curve is constant, the direction at right angles must vary, according to the desired cylindrical element; and the opposite spherical surface would depend upon the sphere required.

From a careful consideration of these facts, the following rules have been formulated for converting ordinary sphero-cylindrical combinations into toric form:—

1. The original prescription must be expressed in its simplest form; except when contra-generic (*i.e.*, + and −), for the correction of Mixed Astigmatism.

2. The base curve is always of opposite sign to the cylinder in the prescription, but has the same axis.

3. The other curve of the toric surface is at right angles, and its power is equal to that of the base curve plus the number of the original cylinder (irrespective of sign).

4. The spherical surface has the power of the base curve, plus the algebraical sum of the original sphere and cylinder; the sign being opposite to that of the toroidal surface. In practice, for purposes of economy, and for facilitating the stocking of "toric blanks," the base curve is a definite power, either 4D., 6D. or 9D., the 6 dioptre curve being that mostly employed; so that, in the following examples, we will use a *base curve of* 6 *D.*

Transpose + 2 sph. ⊃ + 1·50 cyl. ax. 70° into toric form.

This is expressed in its simplest form, so does not require altering. The "base curve" is to be 6D., and from Rule 2 above, its sign is minus, and its axis 70°; *i.e.*,

Base curve −6D., ax. 70°.

The other curve (see Rule 3), is:—

− 7·50 ax. 160°

so that the toric surface is − 6D. ax. 70° ┌ − 7·50. The spherical surface (see Rule 4), is + 9·50, and the complete toric combination reads:—

+ 9·50 sph. ⊃ − 6D. ax. 70° ┌ − 7·50.

Convert into toric form :—

$$- 3{\cdot}75 \text{ sph.} \bigcirc - 1\text{D. ax. H.}$$

Following the Rules (2), the base curve is + 6D. ax. H., and the opposite direction (3), + 7 ax. V.; making the toric surface + 6 ax. H. ┌ + 7. The spherical power (4), is – 10·75D., making the complete toric :—

$$-10{\cdot}75 \text{ sph.} \bigcirc + 6\text{D. ax. H.} ┌ + 7\text{D.}$$

This prescription :—

$$+ 2{\cdot}50 \text{ sph.} \bigcirc - 1{\cdot}25 \text{ cyl. ax. } 110^\circ,$$

requires transposing into its simplest form (Rule 1), when it reads: + 1·25 sph. $\bigcirc$ + 1·25 cyl. ax. 20°, and can now be transposed into (Rules 2, 3 and 4) :—

$$+ 8{\cdot}50 \text{ sph.} \bigcirc - 6. \text{ ax. } 20^\circ ┌ - 7{\cdot}25.$$

If the original prescription is to correct Mixed Astigmatism, then it does not require transposing into its best form, even when not written quite in the simplest way, as these two examples will show :—

$$+ 2 \text{ sph.} \bigcirc - 3 \text{ cyl. ax. } 135^\circ.$$

By Rules 2, 3 and 4, the "toric" is :—

$$- 7 \text{ sph.} \bigcirc + 6. \text{ ax. } 135^\circ ┌ + 9.$$

It will be noted that *the algebraical sum* (Rule 4), of two numbers whose signs differ, *is their difference.*

Take this example, which is expressed in its best form :—

$$- 0{\cdot}50 \text{ sph.} \bigcirc + 1{\cdot}50 \text{ cyl. ax. H.}$$

and its toric equivalent is written from it direct :—

$$+ 7 \text{ sph.} \bigcirc - 6. \text{ ax. H.} ┌ - 7{\cdot}50.$$

The rules followed in these examples are all that are required in actual experience; but in working out theoretical examples (such as may be required in examinations), it is sometimes necessary to transpose into toric form, having the

base curve of the same sign as the cylinder in the original prescription; when the following Rules would apply:—

(*a*) Transpose prescription into its simplest form.

(*b*) The base curve has its axis at right angles to that of cylinder in the original prescription.

(*c*) The other curve of toric surface is equal to the power of the base, plus strength of the cylinder in original prescription, and has the same axis.

(*d*) The spherical surface has the power of the base curve, *less* the number of the original sphere (irrespective of sign), and is of opposite kind to the toric surface.

(*e*) When dealing with contra-generic compounds, the same rules apply; but the spherical curve is equal to the power of the base, *plus* the original sphere.

Two examples will suffice to illustrate the above.

Transpose into toric form, using + 6D. base curve:—

$$+ 1 \text{ sph.} \bigcirc + 2 \text{ cyl. ax. } 105^\circ.$$

From Rule *b* we obtain

$$\text{Base curve } + 6\text{D. ax. } 15^\circ.$$

The other direction (Rule *c*), is + 8 ax. 105°; thus we get the toroidal surface, + 6 ax. 15° $\ulcorner$ + 8; and following Rule *d*, we arrive at the spherical surface, − 5. and so obtain the complete toric:—

$$- 5. \text{ sph.} \bigcirc + 6 \text{ ax. } 15^\circ \ulcorner + 8.$$

This contra-generic compound:—

$$- 0{\cdot}75 \text{ sph.} \bigcirc + 1{\cdot}75 \text{ cyl. ax. V.}$$

by Rules *b*, *c* and *e* is transposed into this "toric":—

$$- 6{\cdot}75 \text{ sph.} \bigcirc + 6. \text{ ax. H.} \ulcorner + 7{\cdot}75.$$

Problems connected with toric lenses have been given, in which a definite spherical curvature is asked for. Although actually impracticable, it is well to know how to do this; and the transposition, under such conditions, is accomplished as follows:—

Reduce the original prescription into a cross cylinder, by taking as one cylinder the power of the sphere in the first

prescription, placing the axis at right angles to the axis of the cylinder in the original prescription. The other cylinder is obtained by adding the original sphere and cylinder together, placing the axis in the direction of the cylinder in the original prescription. When the cross cylinder combination is obtained you take the necessary sphere of the toric lens, which will make the cylinders correspondingly weaker than in the cross form, if the sphere is of the same sign, and stronger if of the opposite kind.

Example :—

+ 3 sph. ◯ – 5 cyl. ax. V. :

changed into cross cylindrical form becomes :—

+ 3 cyl. ax. H. ◯ – 2 cyl. ax. V.

Let us take – 1D. as the sphere in our toric lens; and this will make the cylinders of the toric stronger in one case, and weaker in the other, by this amount, viz. :—

+ 4 cyl. ax. H. ◯ – 1 cyl. ax. V.

making the completed toric combination :—

– 1 sph. ◯ + 4 cyl. ax. H. ⌈ – 1 cyl.

When we take a deep spherical curve, the cross cylinders are more altered in producing a toric lens, as follows :—

Using the same example as last, but choosing – 6.D. as our sphere, the cylinders are changed to

+ 9 axis H. ◯ + 4 ax. V.

making the finished ℞ (or prescription) read :—

– 6 sph. ◯ + 9 cyl. ax. H. ⌈ + 4 cyl.

If the original lens that we wish to alter into a toric form is a plano cylinder, we leave it in this form.

CHAPTER X.

PRESBYOPIA.

The reader may wonder why Presbyopia, which is a condition that every person must arrive at, provided they live long enough, should be mentioned *after* having treated of Hypermetropia, Myopia and Astigmatism. The reason is, because this condition of the eye may be complicated with any of these three errors of refraction; and consequently it is essential that the refractionist should be familiar with the causes and corrections of the several anomalies of refraction before undertaking the study of a defect which may be combined with either of them.

The term "defect," however, is not strictly correct when applied to this condition; as Presbyopia is not by any means an abnormal condition—any more than it is for our bones to become set and brittle with age. It is a natural senile change which comes on with years, being dependent upon the power of the Ciliary muscle—and this, like all other of our organs, gradually deteriorates as we get older, and becomes unable to perform its duty as efficiently as in earlier life. As was explained previously, the power of accommodation gradually but steadily declines from the early age of ten years (when all the other functions of the body are still developing) until seventy years of age; when the power of the accommodation is entirely exhausted, and consequently the near point has receded to infinity—provided that the patient was an emmetrope.

Well, it is when the near point (PP) has receded beyond twenty-two centimetres (nine inches), that Presbyopia is said to exist. Presbyopia, then, consists of a gradual recession of the near point, so that one's reading matter has to be held further away from the eyes than formerly; and the object of prescribing correcting lenses in this condition is, to bring the near point back close enough to the eye to enable the patient to read at a comfortable distance, which is usually about thirty-three centimetres (thirteen inches).

The causes are:—

1. A weakening of the Ciliary muscle, or muscle of accommodation;
2. Loss of elasticity, or hardening, of the Crystalline Lens.

Presbyopia may be defined as that condition of the eye where there is a deficiency in the power of accommodation, due to a weakening of the Ciliary muscle; and a loss of elasticity of the Crystalline Lens, from age.

Presbyopia is not a change in the structure of the eye; as the eye itself is usually perfectly formed, the accommodation only being at fault. Care should be taken not to confound Hypermetropia and Presbyopia, because their corrections and symptoms are very much the same; inasmuch that both require a convex lens, and in both cases the reading point is further away than is normal, and consequently, near work has to be held far away from the eyes.

Yet in every other respect they are diverse; one being an error of refraction, and the other an error of the accommodation. Hypermetropia is due to a shortening of the eyeball, or some other structural defect; while in Presbyopia the eye is perfect in shape, the accommodation alone being impaired.

By reference to the following Table, you will notice that at forty years of age the Amplitude of Accommodation is only 4·5 D., which represents a near point of twenty-two centimetres ($\frac{100}{4 \cdot 5} = 22$). This, then, is the last period at which an

emmetropic eye is able to read without the aid of glasses; as Presbyopia was said to be present when the near point has receded beyond twenty-two centimetres, or nine inches.

TABLE OF ACCOMMODATION IN THE PRESBYOPIC PERIOD OF LIFE.

	Age.	Amp. of Accom. Dioptres.
	10	14
	20	10
	30	7
Presbyopic period of life.	40	4·5
	45	3·5
	50	2·5
	55	1·5
	60	1
	65	0·5
	70	nil.

Presbyopia commences, in an emmetropic person, a little after forty years of age. Although this is the case, all people do not wear glasses when they first feel the want of them; as there is a very foolish (and unfortunately prevalent) prejudice, among the people of this country, against the wearing of spectacles. But in order to protect the Ciliary muscle, and to have the benefit of its assistance as long as possible, glasses should be worn as soon as the necessity for them is first manifested.

Presbyopia is first noticeable at about the age of forty, and increases at the rate of approximately 0·75 D. for every five years after this age, when the person is emmetropic. If the person be hypermetropic, Presbyopia shows itself earlier, and if myopic, at a later period than forty years.

Presbyopia occurs in every eye, without exception; even if the eye be ametropic. The amount of the Presbyopia may be expressed by that strength of convex lens necessary to bring

the working point back to a comfortable reading distance. Convex glasses are used, because the Ciliary Muscle has become weaker, and the Crystalline Lens more set, which makes it difficult for the mechanism of the accommodation to act, and it cannot make the lens sufficiently convex to focus divergent rays on the Retina—therefore we must help the accommodation by making the eye artificially more convex by means of a plus lens.

An emmetropic eye is, as the reader knows, perfectly adapted for parallel rays of light. It stands to reason, then, that it can never require a stronger lens than one whose focal length represents the distance at which the book is to be held, in order to read comfortably.

For instance, to read at fifty centimetres (twenty inches), it will never require more than 2D., because this lens is sufficient to render parallel the rays entering the eye. To read at twenty-five centimetres (ten inches), it will not be necessary to give a stronger lens than 4D., for the same reason.

A presbyopic person is able to use two-thirds of his accommodation for comfortable reading or close work, and the usual reading distance is thirty-three centimetres; therefore no emmetropic presbyope will require more than 3D. to correct his Presbyopia. The following Table shows the Amplitude of Accommodation, and the available amount of accommodation, in dioptres, as well as the lens required to correct the Presbyopia, from the age of forty to seventy, which will be found useful for reference.

Age.	Amplitude of Acc.	Available Acc.	Lens.
40	4·50	3·00	0
45	3·50	2·34	+ 0·66 [0·75]
50	2·50	1.67	+ 1·33 [1·50]
55	1·50	1·00	+ 2·00
60	1·00	0·67	+ 2·33 [2·50]
65	0·50	0·34	+ 2·66 [2·75]
70	0	0	+ 3·00

The figures in brackets represent the nearest lenses obtainable from the trial case, and are near enough for all practical purposes.

It should be perfectly understood that the table here given is only approximate; and you may find, in following the same, that in one case the correction is a little too strong, and in another slightly too weak. But it is a very near approximation, and you will find it most useful in practice. Also bear in mind that you cannot rely implicitly upon the age of your patients; as even if they tell you, they may make a slight error (inadvertently, of course), usually on the side of youth, and inform you incorrectly, which is sometimes the case with ladies.

To verify your correction, if necessary, you can do so by subtracting the glass whose focus represents the receded near point from the lens whose focus represents the distance you wish to make the near point. You measure the near point, of course, by finding the closest distance at which your patient can decipher the smallest reading type. For example, your patient reads at fifty centimetres (which represents 2D.), and the normal distance is thirty-three centimetres (which is 3D.), so that the patient would require for reading the difference between these two lenses, which is + 1D.

The best rule for you to remember in this connection is that *the correction for Presbyopia is that strength of convex lens necessary to place before the eye to enable the patient to read comfortably at a distance of thirty-three centimetres*, or at the distance at which the patient would like to read. In Presbyopia it is best to study your patient's comfort as regards the reading distance.

You test by placing before both the eyes together convex lenses, gradually increasing the strength until you obtain the *weakest* with which your patient is able to see the small type distinctly at the proper distance.

Presbyopia does not interfere with distant vision at all, only affecting the reading, etc., but you should, nevertheless,

always test for distance first, before attempting to correct the Presbyopia, because it may be complicated with any of the various forms of Ametropia.

In the case of a hypermetrope, his available accommodation is very much less for reading purposes than an emmetrope's, because of the amount of accommodation that is constantly used to correct the defect; therefore he will naturally require a stronger convex lens to enable him to read, say at the age of fifty, than a person with normal sight. For sake of example: if the patient is hypermetropic to the extent of + 2D., and his age is fifty, you would add the hypermetropic to the presbyopic correction; which would make the lens for reading + 3·5, because for the Presbyopia at the age of fifty, the patient would require (approximately) +1·50D.

The distance glass, of course, would remain + 2D.

Another case: Age, fifty-five; Hypermetropia in both eyes, + 1D. The prescription for this patient would be:—

Distance, O.U. + 1D.
Reading, O.U. + 3D.

This last is obtained by adding the hypermetropic correction to the presbyopic, which is + 2 (see Table).

If the patient is myopic, the correction for reading in Presbyopia would be weaker than that of an emmetrope at the same age, because the Myopia would neutralize the Presbyopia to a certain extent. Of course, the Presbyopia is present, only the Myopia disguises it, as it were, and the patient is able to read without the aid of convex lenses at a more advanced age than an emmetropic person could.

If a patient has 2D. of Myopia at fifty-five years of age, he would not require any lens at all for reading, because the −2D. of Myopia would neutralize the Presbyopia of + 2D. So you see that Myopia postpones, as it were, the presence of Presbyopia; and that Hypermetropia makes it manifest earlier than is usual in an emmetropic eye.

If at fifty years a patient had Myopia of 1D. in each eye, then the prescription would read :—

Distance, O.U. – 1D.
Reading, O.U. + 0.5D.

In cases of deep Myopia, where two pairs of glasses have previously been necessary; the weaker for reading and the stronger for distance, the presbyopic lens is added to the *myopic reading glass ;* that is, to the weaker pair of the two. In the lower degrees of Myopia, the presbyopic correction is added to the distance glass.

Example.—Suppose the R.E. required – 12 and the left – 10 for distance, and patient had been accustomed to wearing – 9D. and 7D. for the right and left eyes respectively, for reading, until just recently; then the presbyopic correction is added to this latter glass. If the patient is fifty years of age, it would make the reading prescription, R.E. – 7·5, and L.E. – 5·5; the distance lens remaining the same.

From the above you can see the importance of testing distant vision first, and finding out if there exists any error of refraction in addition to the Presbyopia. If there is, you correct it, and add the approximate presbyopic correction to it for reading purposes. If the patient be astigmatic, you do precisely the same as if he were hypermetropic or myopic; that is, you add the degree of Presbyopia to his correction for distance.

Take as an example, a person fifty years old, who suffers from compound Hypermetropic Astigmatism. You add + 1·5D. (the approximate presbyopic glass) to his distance correction, which in this case let us assume to be :—

O.U. + 2 sph. $\bigcirc$ + 3 cyl. ax. V.

The correction for reading would be :—

O.U. + 3·50 sph. $\bigcirc$ + 3 cyl. ax. V.

In the above, you add the + 1·50D. to the *spherical* part of the correction for distance; remembering the rule, " Never

to alter the strength or axis of the cylinder, when you have once obtained the proper one to enable the patient to see the lines in every direction with equal distinctness."

In order to further explain this, let us take another example: Age of patient fifty-five, suffering from Compound Myopic Astigmatism. You find by testing that his correction for distance is:

R.E. $-$ 2 sph. $\bigcirc$ $-$ 1 cyl. ax. H.
L.E. $-$ 2·5 sph. $\bigcirc$ $-$ 0·5 cyl. ax. 160°.

For reading you would give:

R.E. $-$ 1 cyl. ax. H.
L.E. $-$ 0·5 sph. $\bigcirc$ $-$ 0·5 cyl. ax. 160°

You obtain this by adding $+$ 2 (that is, the approximate correction for Presbyopia at the age of fifty-five) to the spherical part of the distance correction; which in the right eye is $-$ 2. These two lenses, being of the same strength and of opposite powers, neutralize each other. The sphere in the left eye was $-$ 2·50; so that, after deducting the $+$ 2 for the Presbyopia, there remained $-$ 0·50 spherical.

You see from this, that although the patient is for distance suffering from Compound Myopic Astigmatism, his defect may be reduced to one of Simple Astigmatism, for reading, by the advent of Presbyopia.

From the above examples, you should find Presbyopia fairly simple to suit. In the first place you test for distant vision, by the means that have been fully explained in former chapters, and add to this the approximate presbyopic correction; which latter you obtain by ascertaining the age of your patient. Or, add to the distance glass (if any), the *weakest* plus lens which allows the patient to read comfortably with a fair range; *i.e.*, a little nearer to and farther from the actual reading point.

Sometimes, when Presbyopia is fairly advanced, your correction may not give the assistance anticipated—the patient

still complaining of difficulty and uneasiness when reading. Providing your prescription for lenses on re-testing is found to be correct, weak prisms, *bases in*, combined with these glasses, will give relief. By adding a prismatic element to the lenses, you render assistance to the convergence by allowing the eye to turn outwards somewhat, and so lessen the strain upon the internal recti; in this way maintaining the association between accommodation and convergence, the want of harmony between these functions being the cause of the trouble.

In conclusion I might repeat:—

The addition for the Presbyopia is *always* the same in each eye; and it should be added to both the eyes at once.

The amount necessarily depends upon the accommodation the patient possesses; and the correction should always be added to the spherical part of the distance glasses, leaving the cylinder (if any) unaltered in either strength or axis.

If any Ametropia is present, you would correct that before testing for the Presbyopia; and by rendering the eyes artificially emmetropic, equalize any difference there may be.

Your object in testing for Presbyopia is, to enable your patient to read in comfort at the normal reading distance; or at the distance at which he would like to read.

Glasses should be worn as soon as their need is felt; and with the steady advance of Presbyopia, their power should be gradually increased. This increase should not occur more frequently than every three or four years; or at possibly even longer intervals than these.

Occasionally, the addition for reading, in Presbyopia results in the prescription being incorrectly written, as follows:—

R.E. $+ 1 \bigcirc - 2$ ax. 30°.
L.E. $+ 2 \bigcirc - 3$ ax. 180°.

After the addition of, say, $+ 1$ for reading, it would be:—

R.E. $+ 2 \bigcirc - 2$ ax. 30°.
R.E. $+ 3 \bigcirc - 3$ ax. 180°.

This, of course, can be transposed to:—

R.E. + 2 cyl. ax. 120°.

R.E. + 3 cyl. ax. 90°.

Lastly, do not stick to any hard-and-fast rule in the selection of the glasses necessary to correct the Presbyopia, but study the comfort of your patient.

SYMPTOMS.

A presbyope will come to you, complaining that he has always had good sight, but lately has experienced a difficulty in maintaining distinct vision when reading, writing or possibly sewing, especially at night time. He will probably complain also of a feeling of fatigue in the eyes themselves, after any close application; or that the reading matter has to be held further away than formerly. The patient will try to obtain the strongest possible illumination; sometimes placing the light between the book and his eyes—this increased light makes patient's pupil contract, and thus lessens the circles of diffusion.

At the presbyopic period of life—that is to say, after about forty years of age—there are several diseases that are apt to occur; some of which are more or less serious, and unless detected in time, and sent to the oculist at once, may terminate in irreparable damage to the sight. Therefore it would not be untoward to give a few symptoms by which the refractionist may recognise one or two of the most frequent of them.

If a presbyope requires his reading correction changed for *weaker* convex lenses, instead of stronger ones, Cataract should be suspected, and if any symptoms of it are present, patient should be informed of the fact. Nothing can be done to remove the Cataract until it has enveloped the whole of the lens; when it is said to be "ripe" for operation. But unless both eyes are affected, it is not advisable to operate, as the inequality of the vision would be too great to be comfortable. If the Cataract is small and central, vision will be improved in a dull light, or by shading the eyes; when marginal, vision is best in

a bright light, which contracts the pupil, and so covers the peripheral portion of the lens. It is recognised by an opacity of the Crystalline Lens, which on oblique illumination appears white; but when looked for with the Ophthalmoscope, it will appear black.

Needless to say, the removal of the Crystalline Lens, which the operation for Cataract necessitates, is beyond the domain of the refractionist, and the patient should be sent to a surgeon-oculist when there is Cataract present.

Glaucoma is one of the most dangerous diseases that the eye is subject to in the presbyopic period; and threatens the individual with a total loss of vision. It is an abnormally high tension of the eyeball, which is sometimes caused through the dislocation of the lens; or, the more recent authorities attribute it to interference with the free passage of the filtration angle at the base of the Iris (see Chapter on Anatomy); although the causes are not yet thoroughly understood. The first symptom that would appeal to the refractionist is the rapid increase of what is supposed to be "old sight"—therefore, in cases where the convex lenses have frequently to be changed for stronger ones, Glaucoma should be carefully looked for; and if any symptoms of it appear, no near work should be allowed, especially by artificial light. Any Ametropia that may be present should be corrected, and the glasses worn constantly, so that the eyes are not strained. A few symptoms by which the reader may be able to recognise Glaucoma are enumerated below:—

1. Rapid increase in strength of convex lens necessary for reading, in Presbyopia.

2. The suspected eye, when compared with a normal one, will feel very much firmer to the touch. This hardness of the eyeball is the chief and essential symptom of Glaucoma. In order to ascertain the tension of the eyeball, the patient should loosely close his lids, and look down. The observer

should then, with his fingers close together, press the eyeball a little—this pressure should be directed downwards. Any abnormal tension will be readily detected, when compared with the touch of the normal eye.

3. The Cornea may, or may not, appear steamy; and the anterior chamber is usually shallow, on account of the Lens and Iris being pushed forward.

4. The patient may complain of seeing haloes around a light; although this is not an infallible sign, and should not be considered unless one or more of the other symptoms are also present—as sometimes, by merely correcting the error of refraction, these haloes disappear.

5. The Pupil is widely dilated and fixed, so that it does not respond readily to light.

6. The patient may complain of neuralgia in forehead, temple, and sometimes passing down the side of the nose. This is brought on by pressure on the Ciliary nerves in the Sclerotic.

There are many other symptoms besides the above, such as cloudiness of the Humours; but they are not seen unless with Ophthalmoscope, and as it is not intended here to discuss anything that cannot be distinguished with the trial case, or that could not be seen with the unaided eye, further discussion on the subject must be left for some future time. However, should one or more of the above symptoms be present, it is advisable not to hesitate, but send your patient direct to the surgeon-oculist.

Another defect which presents itself at this period of life is Acquired Hypermetropia. This is not a disease; and since its effect on the vision is only slight, we will not waste much time over it, but merely state what it is, and its effect on the emmetropic and ametropic eye.

The cause of Acquired Hypermetropia is a hardening and enlargement of the Crystalline Lens, which diminishes its

refractive power. The degree in which it progresses is as follows:

Age.	Amount.
55	0·25D.
60	0·50
65	0·75
68	1·00
70	1·25
75	1·75
80	2·50

So it is obvious that this development is not sufficient to be seriously taken into account, until after the patient is about sixty-five or seventy years of age; yet it will, nevertheless, make an emmetrope "far-sighted," and a hypermetrope more hypermetropic, and the myope less ametropic, when this acquired condition has developed to any extent.

CHAPTER XI.

STRABISMUS.

The word "Strabismus" is from the Greek, meaning "turning aside," and this defect is commonly known as "Squint," or "Cross-eye."

As the name implies, this is a condition in which the visual axes of the two eyes are not directed to the same point.

The eyeball is kept in position, and its movements are entirely governed by six small muscles; and as long as there is nothing to interfere with or alter the natural equilibrium of these muscles, the two eyes work together in perfect harmony. But should, for any reason whatever, one of these muscles receive greater or less impetus than another, the eye will deviate from its natural direction, and squinting is the result.

Strabismus is caused by either over-action, weakness or paralysis of one or more of the extra-ocular muscles; and may be divided into two principal forms—Paralytic and Concomitant. We will consider the Paralytic variety first.

This is due, of course, to paralysis of one or more of the external muscles of the eye, so that there is a difficulty in turning it in the direction of the affected muscle. A characteristic of this variety is double vision, which cannot be corrected by means of lenses; but should the Squint produce Diplopia (that is, double vision), it can be counterbalanced by the proper application of prisms. We all know the action of a prism on light traversing it; so the following will be understood by the reader.

USE OF PRISMS TO PREVENT DIPLOPIA DUE TO PARALYTIC STRABISMUS.

In order that our two eyes (each of which, of course, receives a separate image of external objects on the Retina) may see an object as one, it is necessary that the rays of light emanating from the objects under observation, should focus on corresponding parts of the two Retinæ: if they do not, Diplopia results. It is seen, therefore, that to overcome this condition, a prism must be used, so as to deviate the rays of light entering the affected eye, from their original course, in such a way that they fall upon the same portion of this eye as of the perfect one.

Take, for example, a patient regarding an object which is focussed on the yellow spot of the right eye; the left one, being turned inwards too far, receives the rays upon the nasal Retina, and therefore projects outward to the left, causing a false image to be seen to the left side of the object. A prism of adequate strength, when placed with its base outwards, towards the temple, deflects the rays from the object towards the temporal Retina, so that they fall on the Macula Lutea (yellow spot), and in this manner it corrects the Diplopia (see Fig. LXXXIV.).

The subject of Paralytic Squint is not considered exhaustively here, because it cannot be remedied by lenses; and this book is written in order to teach the best methods of prescribing for all defects that can be corrected by lenses.

We will, therefore, now consider the more common form of Strabismus, namely, the Concomitant or non-paralytic variety. This form is due to either the over-action or weakness of the muscles governing the movements of the eyeball, and can be corrected by suitable glasses.

The first thing that presents itself to the reader's mind will naturally be the necessity of distinguishing between these two varieties of Strabismus; since the one can, and the other cannot be remedied by the proper selection of lenses. This is

accomplished by directing your patient to look with both eyes at a pencil or other suitable object, held at about forty inches, or one metre, away. Without moving his head, the patient should follow the object, which you move in all directions—up and down, to the right and left.

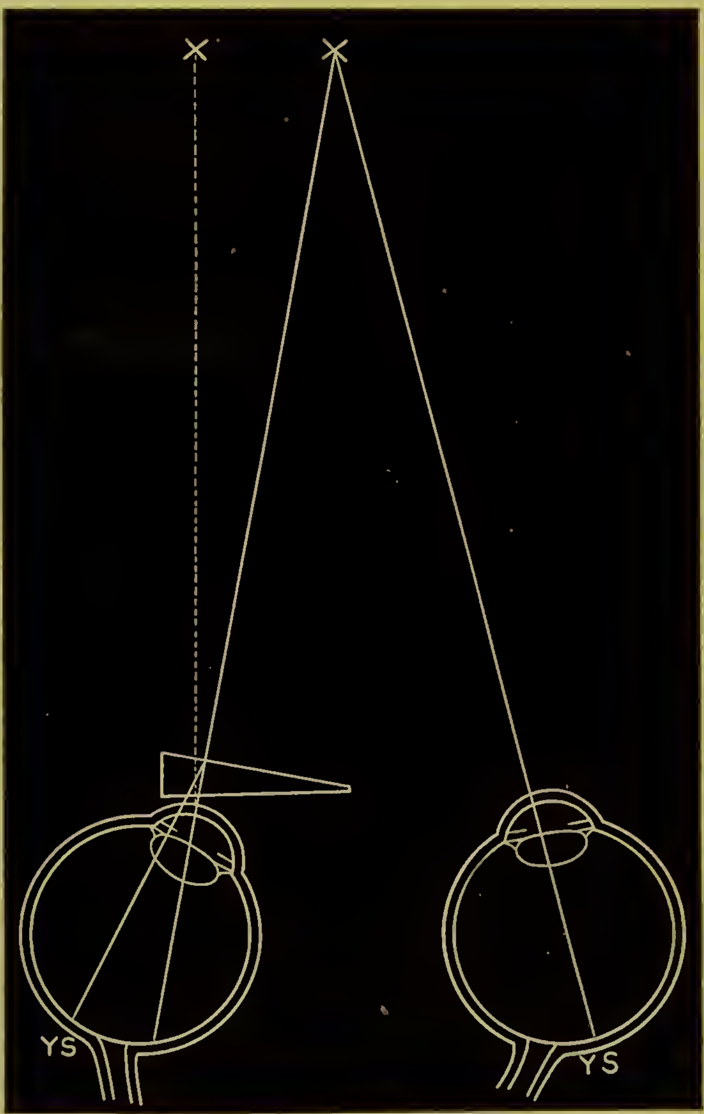


Fig. LXXXIV.

If the Squint is Paralytic, the deviating eye will not follow the "good" one in every direction of vision; but will move to a certain position, and then stop, whilst the other eye continues the journey alone. But in the Concomitant form, the "bad" eye will follow the "good" one in all directions in which you

move the object. From this it should not be inferred that both the eyes fix the object; as, if this was the case, there would be no Strabismus. But, by the eyes following one another is meant that the bad eye will maintain its relative position to the other all the while. This, then, is the way to differentiate between Paralytic and Concomitant Squint; and it is to be the first step you should take in examining such a patient.

Another way of distinguishing between these two varieties of Squint, is to employ the "Screen Test," as described on page 205, and notice the difference between the primary and secondary deviations of the eyes. In Paralytic Strabismus, the secondary deviation is always the greater; whereas, in Concomitant Strabismus, the primary and secondary deviations are equal. The primary deviation is the turning of the affected eye on the "good" one fixing some distant object; the secondary deviation is the deviation of the "good" eye, on its being covered, and the "bad" one made to fix the object.

Concomitant Strabismus is divided into two chief kinds: Convergent and Divergent.

Convergent Strabismus, as the name implies, is the state of affairs when one or both eyes deviate inward too far towards the nose. This is generally due to some uncorrected error of refraction; which, in ninety-nine cases out of every hundred, is Hypermetropia.

This defect causes Convergent Squint, on account of the excessive nerve force which the constant use of the accommodation necessitates being given to the third nerve which supplies it. It is easily understood that if there is a certain amount of force to be distributed among several nerves, if one receives more than its natural proportion, it must be to the detriment of the others.

Thus it is that the stimulus sent to the Internal Rectus by the third nerve is greater than that given forth by the sixth to its antagonistic muscle, the External Rectus; and the

resultant effect is, that the internal muscle gains the day, and pulls the eyeball inward, constituting Convergent Strabismus. To obviate a tedious repetition, the reader is requested to refer to page 103, where it is fully explained how it is that Hypermetropia produces Convergent Squint.

The reason why all uncorrected hypermetropes and myopes do not suffer from Strabismus is, that some become accustomed to exercising the function of accommodation in excess of convergence, and *vice versâ;* thus disassociating these two functions.

Divergent Strabismus is when one eye turns outward too far; and is due, as a rule, to uncorrected Myopia.

Myopia produces this result on account of the accommodation being used so little in this defect of eyesight, that the nerve force supplied to the Internal Rectus, which is supplied by the same nerve as the Ciliary muscle—*i.e.*, the third—is very little; so that the External Rectus receives the most stimulus from the nerve centre (the brain), making it the stronger of the two opposing muscles—and consequently it pulls the ball outward, so that Divergent or External Squint is the result. (This was explained before, in Chapter VII. on Myopia.)

It is essential, in endeavouring to correct Strabismus, to ascertain the cause; and if this is fully removed, Nature will do the curing. The use of prisms, instead of correcting the cause of the muscular insufficiency, would aggravate the defect, and not relieve it; as they only stimulate the muscle (which, mind you, is already weak, through not receiving sufficient nerve power from the brain) to do an extra amount of work.

The function of a muscle is, to be the medium through which nervous energy is applied; just as an electric bell is to the battery which supplies it. Cut off the electricity that operates the bell, and it will not ring; and so it is with the muscles—shut off their supply of nerve force, and it is inconsistent to expect them to act.

If this is clearly understood, it will be easily appreciated why I say, correct the cause of the trouble in muscular weakness, and in this way allow the machinery to right itself; when the muscle trouble will disappear.

If prisms were given to be worn constantly in such a case, it would have the same effect as making a person who had just recovered from an attack of fever run a race, without first giving him back his strength by proper nourishment. The man would run for a little time; but he would presently stop, in a very much worse condition than when he started.

Therefore, always ascertain the cause of the complaint; and if it is Hypermetropia, it is advisable to correct it in *full;* or in other words, slightly *over-correct* the manifest error, and let the glasses be used constantly. If Myopia was the cause of the Squint, you would *not* over-correct it; but in this case, also, the glasses should be worn both when regarding near objects and when looking at a distance.

Of course it cannot be expected in every case, as soon as the glasses are put on, that the Squint will immediately cease; it will take some time for the brain to recuperate its power, and the Strabismus to disappear. At first, also, the glasses may not feel very comfortable; but the patient should be told to persevere—when in a short time, the unpleasantness will pass away.

It sometimes takes as long as six, or even twelve, months for the Squint to be entirely removed. But the length of time that it takes is dependent very much upon the age of the patient; and also upon the time the Strabismus has been present.

I have known cases in which the Squint was improved as soon as the correct lenses were worn for a little time; and others in which the Strabismus quite disappeared in a period of two or three months.

The younger the patient, the more successful will you be in this method of treatment; as in elderly persons the muscles

are more set, and consequently more difficult to coax back to their normal condition.

The reason why convex lenses are given to correct Convergent Strabismus is, that they relieve the accommodation of part of its work, as in Hypermetropia; and at the same time exert a positive effect in diminishing the convergence which is so closely associated with it. Concave lenses, on the other hand, by stimulating the accommodation into action in near vision, as in Myopia, invite also increased action of the Internal Recti muscles, with a corresponding relaxation of the External Recti; and thus afford relief in cases of Divergent Strabismus.

According to Javal, a temporary paralysis of the accommodation may produce Convergent Strabismus, as follows:—

"A patient whose accommodation suddenly fails, is obliged to make a great accommodative effort, which is facilitated by an excessive exertion on the part of the convergence, that is, Convergent Strabismus."

We have so far been considering those conditions in which there is an actual deviation of the eyes from parallelism, or associated muscular action; but there is also a latent insufficiency of the muscles, or what is more commonly styled Heterophoria; when, although the tendency towards deviation is present, by an effort of will the eyes are kept straight. Neglected errors of refraction are directly instrumental in producing this want of equilibrium; in the same way as they are the cause of the majority of cases of manifest concomitant Squint.

The effort of accommodation necessary for the hypermetrope to exert in overcoming his defect at a distance, and when viewing near objects, involves the convergence in natural proportion; but since this would destroy single binocular vision, the desire for convergence is counteracted by a corresponding stimulus being sent to the external Recti, which maintains the even balance of the eyes. When such unnatural disassociation of these functions can be accomplished,

the individual does not squint; it is when they work in harmony under such conditions that the deviation occurs.

The same reasoning applies in Myopia; only then, it is the accommodation which is held in check, and the convergence which is in excess of the Ciliary effort.

Thus Heterophoria is when there is a tendency of the eyes towards deviation, which is not given way to; in contradistinction to Strabismus, where there is an actual turning of the eyes.

Orthophoria is a word used to express a normal balance of the extra-ocular muscles.

Heterophoria is divided into :—

Esophoria, meaning a tendency towards Convergence, or insufficiency of the external Recti.

Exophoria, meaning a tendency towards Divergence, or weakness of the internal Recti.

Hyperphoria means such weakness of one inferior Rectus as tends to throw the visual line of the affected eye higher than that of the normal eye.

Cataphoria indicates insufficiency of the superior Rectus, or a tendency of the visual line below that of the unaffected eye.

Hyperesophoria indicates weakness of the superior or inferior and the external Recti muscles.

Hyperexophoria denotes insufficiency of the superior or inferior and the internal Recti.

Cyclophoria indicates a want of equilibrium on the part of the oblique muscles.

Generally, the letter R or L is used before the word Hyperphoria, to indicate which eye is the higher. Thus, if the visual line of the right eye is above that of the left, it is called R. Hyperphoria; and if the left eye turns upward above the right, the condition is termed L. Hyperphoria. The letters R and L are also used before Hyperesophoria and Hyperexophoria, to indicate which eye is hyperphoric.

It is sometimes found necessary, in addition to correcting the error of refraction in a case of Strabismus, to exercise the

weak muscle, before you are able to restore it to its natural strength.

EXERCISES TO STRENGTHEN THE INTERNAL RECTI.

Let your patient fix a pencil or finger, held as far away from the eyes as possible, and gradually draw it towards the face. If, whilst doing this, Diplopia should be produced, the exercise should be stopped, and repeated from the original distance.

Another effectual method of exercising the muscles is to place your patient standing a foot or so away from a point of light on a level with his eyes, and tell him to look intently at it. Place in the trial frame a pair of weak prisms, bases out, in front of his eyes. Now tell him to walk slowly backward, keeping his eyes fixed on the light all the time. If Diplopia develops at any distance nearer than twenty feet, the patient must raise the prisms and return to his original position, and begin over again.

By repeating this several times, it will be found that a pair of 5 or 10^{Δ} prisms can be overcome at twenty feet. When this distance is reached without causing Diplopia, patient should be told to stay at that distance for about half a minute, still keeping the light single; then to raise the prisms, and still keep his eyes looking at the light for another thirty seconds or so.

These exercises should be repeated about three times a day and should always be conducted with the patient wearing his ametropic correction; and they must be continued until the patient can overcome prisms slightly in excess of the normal power of the interni, which is generally about 25°; otherwise, when the exercises are stopped, the muscles will weaken a little, and be of less strength than the average power—but by bringing them up above the normal, you allow for the reaction that will come.

The interni are the only muscles which can be brought up to the normal power by exercising; little or no benefit being derived when such methods are applied to the other muscles.

In muscular insufficiency, or Heterophoria, there are several tests by which to ascertain the weak muscle and the amount of the defect. In rare cases, when the correction of the error of refraction does not rectify the Squint after giving it a thorough trial; or when there is no error present; or, as sometimes happens, when refractive error is not the cause of the trouble, prisms may be used for occasional wear, as the case demands.

The various tests will now be given for this purpose.

THE SCREEN TEST.

This is for finding out if there exists any muscular inequality or not; and is not intended for ascertaining the prismatic correction of any existing insufficiency. It consists simply in covering first one eye and then the other with a card, or the blank disc from the trial case; your patient then fixing his attention on some distant object with the uncovered eye. If the eye changes position on being uncovered (the disc being placed before the other eye), it proves muscular insufficiency, and shows that the two eyes were not directed to the same spot. If the eye, when uncovered, turns outward, it shows Esophoria; if it turns in, it is Exophoria. If it moves upward, on being uncovered, it shows Cataphoria; but should the eye turn downwards, it indicates Hyperphoria.

The same test can be made by placing over the eye you are testing the ground disc, which is sufficiently opaque to prevent the patient from seeing anything; but the observer can tell, on looking through it, the direction in which the covered eye is turning, and in this manner find out whether it deviates up or down, to the right or left.

PRISM MUSCLE TEST.

To test the *Internal* and *External* Recti, place in the trial frame before the right eye (testing this one first), a prism of

about 10 to 15^{Δ}, base up, and direct the patient to look at some distant object with both eyes, and he will see two objects, one above the other. The lower one, of course, belongs to the eye over which the prism is placed; that is, the right eye. If the two objects are exactly on the same vertical line, thus , the internal and external muscles are normal. But if the lower image be seen to either side of the other, it shows that one of these muscles is weak. If the lower image is to the left of the higher, , it is the Internal Rectus that is weak (Exophoria), and if it deviates to the right side, like this , the External Rectus is at fault (Esophoria).

The correction is that strength of prism, base in or out, as the case may be, that brings the lower image into the same line as the other. The base of the correcting prism is placed in the same direction as the deviating object; that is, if the object is seen to the right, then the base of your correcting prism would be placed before the eye towards the temple (base out).

To test the *Superior* and *Inferior* Recti, cause Horizontal Diplopia, by placing a fairly strong prism, base out, before the right eye; and on directing patient to look at a suitable object with both eyes, he should see two exactly on the same horizontal line, so , if the superior and inferior muscles are normal. The inner image in this case belongs to the right eye, and is the one to be watched. If the inner or left image is seen above the other , it shows weakness of the Superior Rectus (Cataphoria); and the strength of the prism, base up, that

that brings the inner image into the same horizontal line as the other is the correction. If the inner or left image appears lower than the other, , the Inferior Rectus is weak (Hyperphoria), and the correcting prism is that one, placed base down, which brings the two images into the same horizontal line.

The prism, it will be noticed, is placed *with its base* in the same direction as the deviating object. But it should be remembered that the indications are just the opposite to the right eye, when testing the left one. Instead of the Internal Rectus being the weak muscle, when the image is seen to the left (as it is when testing the right eye), it shows insufficiency of the External Rectus, if the left eye is being tested. This is easily understood when you know that *the direction in which the image is seen* shows the position of the weak muscle. The left of the right eye is, of course, the nasal side; and the left of the left eye would be the temporal side—just the reverse.

MADDOX ROD AND GROOVE.

The Maddox Rod is one of the favourite methods of testing the ocular muscles. It consists of a glass rod, either white or

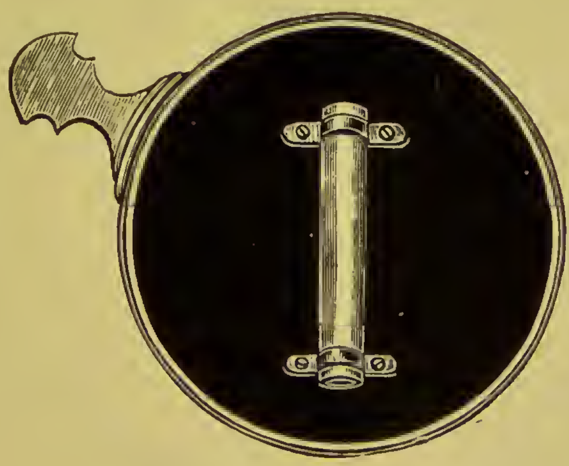


Fig. LXXXV.—The Maddox Rod.

red, fitted into a slit cut in some opaque substance; and forms a very strong cylinder. So that a candle viewed through it

instead of appearing its natural shape, is so distorted that it prevents the eye regarding it as the same object, and so disassociates the tendency of the eyes to assume single vision—the object being to enable the eyes to act independently of each other.

This test is best conducted with the patient wearing his focal correction, if any.

To test the *Internal* and *External* Recti: Place the rod horizontally before the eye you wish to test, say the right one; and direct your patient to fix his attention on a distant light, a candle (six metres, or twenty feet, away, if possible); when he will see the candle in its proper form, and if his muscles are

Fig. LXXXVI.

Fig. LXXXVII.

Fig. LXXXVIII.

normal, a line of light running straight through it (see Fig. LXXXVI.). But should the line of light appear to the right of the candle (Fig. LXXXVII.), then the External Rectus is weak; and the strength of the prism, base out, that brings it directly into the centre of the candle is the correction.

If the line of light is to the left of the object (Fig. LXXXVIII.), then the internal muscle is weak; and the strength of the prism, base in, that brings the line into the centre of the candle is the measure of the insufficiency.

The indications are exactly the opposite to the above when testing the Internal and External Recti of the left eye.

To test the *Superior* and *Inferior* Recti: Place the rod vertically before the right eye, and if these two muscles are

of normal balance, the patient will see the candle with a horizontal line of light directly through it (see Fig. LXXXIX.). If the Superior Rectus is weak, the line of light will be seen towards the top of the candle; and if the inferior muscle is at fault, the line will be towards the lower part of it (see Figs. XC. and XCI.). The correcting prisms would be placed bases up and down respectively.

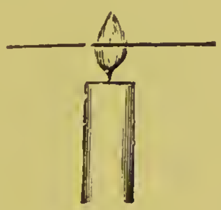


FIG. LXXXIX.

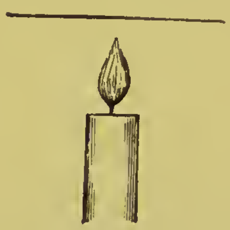


FIG. XC.

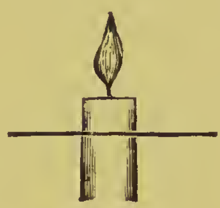


FIG. XCI.

The "Groove" is used in the same way as the "Rod" just described.

MADDOX DOUBLE PRISM.

This consists of two prisms, fixed base to base, and has the property of doubling any object viewed through it. It is for testing the Recti and Oblique muscles, as well as for compound insufficiencies.

You place it in the trial frame, *always* with the bases *horizontal;* and in front of the eye you are *not* testing. For example: When testing the right eye, you place the "double prism" before the left one, and a red glass in front of the right eye. It is as well at first to leave the blank disc before the red glass in front of the right eye for a moment or two, whilst the patient looks at some distant object—say a door-knob—so as to help in the disassociation. The patient will naturally see two knobs with the left eye (as he is looking through the two prisms), one above the other; when

you remove the blank disc from the right eye, he will see three, the centre one being red, so . If the red one is directly between the other two, there is no muscular trouble present (Orthophoria); but if one of the Recti muscles is weak, the red knob will be seen either up, down, to the right or left, as the case may be.

If the external and superior Recti are weak (left Hyper-esophoria), then the red knob will be seen upwards and to the right ; if it is seen upwards and to the left,  the internal and superior Recti of the right eye are weak (left Hyper-exophoria).

Insufficiency of the inferior and external Recti (right Hyper-esophoria), is proven when the red object is seen down and to the right, thus . Should it be seen like this,  down and to the left, the inferior and internal Recti muscles are at fault (right Hyper-exophoria).

The base of the correcting prism is always placed in the direction in which the red knob is seen; and is of sufficient strength to bring the red image exactly between the other two.

To test the *Oblique Muscles:* direct your patient to look with both eyes at a card on which is drawn one horizontal line, the double prism being before one eye, and nothing in front of

the other, and if his muscles are normal, he will see three lines like this—

FIG. XCII.

all parallel and equi-distant.

Should they appear thus—

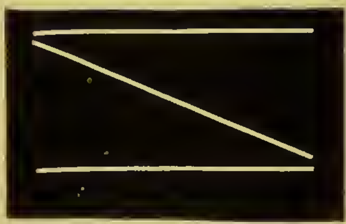


FIG. XCIII.

it shows insufficiency of the inferior Oblique (+ Cyclophoria), when testing the right eye, and of the superior Oblique (– Cyclophoria), when testing the left eye.

When seen in this way—

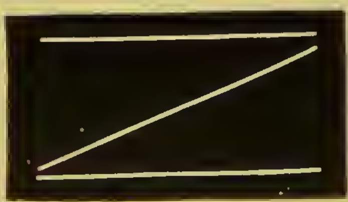


FIG. XCIV.

it indicates weakness of the superior Oblique of the right eye, or of the inferior Oblique when testing the left eye.

In the foregoing tests, one eye has before it either a prism or Maddox Rod or Groove, and consequently there is no room left in front of this eye for your correcting prism. In those cases where the cell of the trial frame before the eye you are testing is occupied, you may then put the correcting prism

before the other eye. It is immaterial which eye the correcting prism is placed before whilst testing, so long as the base of the prism is in the desired direction.

If, for example, when using the Maddox Rod before the right eye, the "line" appears to the right of the flame, indicating insufficiency of the right externus, the correcting prism may be placed in front of the left eye, base *outwards.*

It is well, in these examinations, to place the "test object" (that is, the prism, rod or groove) before the eye possessing the better visual acuity; and during the test, patient should wear his ametropic correction.

In prescribing prisms, only a partial correction is advisable; about two-thirds, or even less, being considered sufficient. This may be placed all before one eye, or else divided between the two, so long as the bases of the prisms are placed accurately; that is, both bases in, *or* out; and when correcting vertical insufficiencies, one base is placed up, and the other base down. Understanding how Ametropia influences the equilibrium of the extra-ocular muscles, it follows that, in Esophoria with Hypermetropia, a *full* correction (or a slight over-correction) of the Hypermetropia is called for, since the accommodation in such cases requires restraining; and in Exophoria with Myopia, any Myopia should also be fully corrected (*not* over-corrected), to induce accommodative effort. If, however, Esophoria should be associated with Myopia, then under-correct, so as not to invoke the accommodation; and in addition, assist the weak muscles with prisms.

In Exophoria with Hypermetropia, an under-correction is again required in this instance, in order to stimulate the accommodation; together with the assistance of prisms.

Evidently, when these conditions just mentioned are found together, the refractive error cannot be the fundamental cause of the muscle trouble.

Vertical insufficiency (that involving the Superior or Inferior Rectus) is not so common as weakness of the horizontal

muscles (the External and Internal); but when present, it more frequently requires the help of prisms; and any slight tendency to over-converge or diverge often disappears without treatment, when the vertical balance is corrected.

RULES.

1. Never prescribe prisms until you have given ordinary lenses a thorough trial, and found them of no use. It is only the exception when such is found to be the case.

2. When prisms are prescribed, they are more frequently given for occasional use; they are seldom required for constant wear.

3. Only then give about two-thirds of the correction, never the full amount.

4. The prismatic correction may be divided equally between the two eyes, both bases out or in, as the case demands.

5. In Hyperphoria, place the base up before one eye, and down in front of the other.

6. When prisms are prescribed, patient should return for re-examination in a few weeks.

7. Remember that the rational treatment for Strabismus or muscular insufficiency is to remove the cause entirely, and trust to Nature to do the rest. Therefore you see that prisms are seldom required.

8. When treating for Squint by correcting the error of refraction, the glasses must be worn constantly, both for distant vision and for close work.

CHAPTER XII.

APHAKIA.

This term is derived from the Greek word "Phakos," a lens, to which Donders added the negative prefix "a"; thus the word "Aphakia" (meaning the absence of the Crystalline Lens) was formed.

This condition is caused generally by an operation, as for Cataract; or it may be due to an injury or puncture of the lens, which, when acted upon by the Aqueous Humour, after a while dissolves. In either case, the refraction of the eye is left extremely hypermetropic.

We have seen, in a former chapter, that should there be a diminution of the refractive power of the eye, it produces Hypermetropia; or, to put it into other words, parallel rays of light, instead of being brought to a focus exactly on the Retina, meet it before coming to a focus. So it is in Aphakia; but in this condition of the eye, instead of there being a congenital diminution of the refractive power, a greater part of the refractive media has been taken away, resulting, of course, in much the same thing—the difference being that in the latter case the eye is left very much more defective than in the former. This is easily understood when you remember that the Crystalline Lens contributed the greatest and most important portion of the dioptric apparatus of the eye.

Since the Crystalline Lens is absent, it is obvious that there can be no accommodation whatever. Consequently, an aphakic patient will be unable to read near at hand with his

distance correction, but will require a different strength of lens for various visual distances, as for reading, or playing the piano or organ, and for wearing when out of doors.

In Fig. XCV. we see an aphakic eye, and notice that parallel rays are brought to a focus beyond the Retina, supposing such a thing to be possible. And when the patient views near objects, the rays are focussed still further behind.

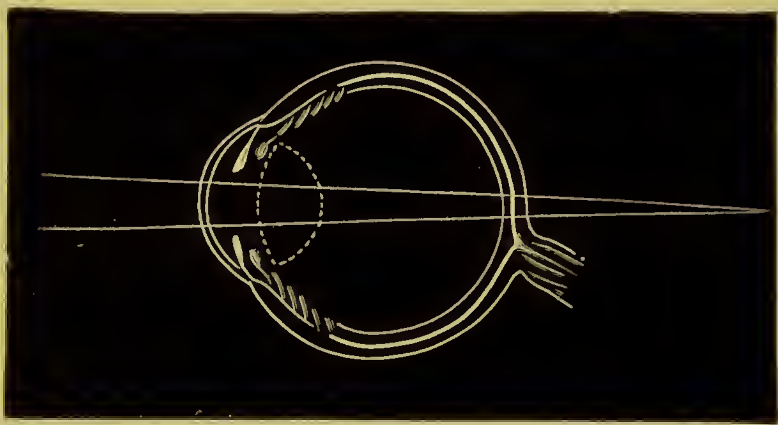


Fig. XCV.

By the above, you can see at once what kind of lenses should be used to correct this defect. The Crystalline Lens having been removed, you must replace it by putting before the eye such a convex lens as will equal the strength of the Crystalline Lens that was within the eye; and on account of there being no accommodation, you must prescribe a stronger lens for reading or near work.

The average power of the Crystalline Lens outside the eye equals about + 11D.; so the distance correction for Aphakia is about 11D., provided that the patient was emmetropic before the operation. And for reading, a slightly stronger pair than this should be given. The rule to remember in selecting glasses for near work is as follows:—

Add to the distance correction a convex lens whose focus represents the distance at which your patient wishes to read. These lenses, of course, if used for *distance*, would make the

patient myopic to the extent of the difference between the distance and reading glasses; and conversely, if the distance glasses were used for reading purposes, it would make the eye hypermetropic.

To illustrate this rule for ascertaining the necessary reading correction, we will take the following example:—

Your patient sees best at a distance with + 11D. You now ask him at what distance he would like to read; and he either tells you, or shows you this by holding his book or test type at the requisite distance, which you judge to be about twenty-five centimetres (ten inches); or, to be more accurate, you can measure the distance.

Now, by dividing the number of centimetres at which the patient likes to read into one hundred, you obtain the additional glass required for close work, which in our example is 4D.; so that in this case your prescription (assuming that both eyes are alike) would read:—

Distance, O.U. + 11D.
Reading, O.U. + 15D.

If you wish to arrive at your patient's reading glass in a quicker way than the above, you can always add to the distance correction + 3D.; which in the great majority of cases represents the reading point—that is, thirty-three centimetres from the eye.

The above remarks are all perfectly accurate, provided that your patient was emmetropic previous to the removal of his Crystalline Lens. But what difference would it make if he had been ametropic before that time? Only this:—

That if the patient was previously hypermetropic, this existing error would have to be added to the average correction for the Aphakia; and in the event of Myopia being the former condition of the eye, the aphakic correction would be proportionately weaker, the Myopia partly neutralizing the Aphakia.

However, since it is too late to ascertain the degree of any pre-existing error of refraction, we cannot arrive at the

correction of the Aphakia by any arithmetical process, but must test our patient systematically with the trial lenses, in the manner now to be given down.

Aphakia may be experimentally determined by the absence of two of Purkinje's images (for full description, see page 12)—those formed on the anterior and posterior surfaces of the lens; as naturally, if the lens has been extracted, only the corneal image will be seen.

There is no necessity for beginning your test with the usual + 0·50D. sphere, as this would not have any appreciable effect upon your patient's vision, for the simple reason that he is practically blind without any glasses. So that a very much stronger lens is necessary, to be placed in front of the eye before you can improve the sight sufficiently to enable the patient to read any letters on the Test Chart.

ROUTINE OF TESTING.

1. First of all, place your patient in a chair at the appropriate distance from the test types; adjust the trial frame, and place the blank disc before the eye not being tested. (Previous to this, you have paid attention to your patient's remarks, and found out that about two or three months ago[1] he had his eyes operated upon for Cataract, and that he has now come for glasses, according to the instructions he received from the doctor who performed the operation.)

2. Find the acuteness of vision; and then hold before his eye a + 10D., with which patient will see very fairly. Increase the strength, until you obtain the best results possible.

3. If you have to increase the lens as much as, say, for example, to + 15D. or so, before arriving at the best correction your patient was probably hypermetropic before the operation, to the amount of + 4D.—this being the difference between

[1] Glasses should never be given for constant use sooner than two or three months after the Cataract operation.

your correction and the average plus glass required by an aphakic patient who was emmetropic previous to this condition.

4. If the patient was myopic previously, you will find that the + 10D. will make the vision tolerably good; but on trying + 11, it would make vision worse. You, therefore, try + 9D., and gradually decrease your glass until you obtain the best correction you can. The difference between this and + 11D. indicates the approximate amount of the Myopia present.

Although, as shown above, the error of refraction that was present before the operation appreciably alters the distance correction, the same rule holds good in any of the above cases, as far as close work is concerned.

The rule is, to add the convex lens whose focus represents the distance at which the patient wishes to read to the distance lens—that is, an addition of + 3D. for thirty-three centimetres; + 2D. for fifty centimetres; and + 4D. for twenty-five centimetres; when this is the distance which your patient requires the glasses for.

When dealing with such powerful lenses as are used for Aphakia, a slight alteration in their position in front of the eyes considerably influences their effective power; so that by adjusting the spectacles on the nose, an artificial accommodation can be produced. Take a case to illustrate this. Supposing a person required for distance, O.U. + 11D., and for reading, O.U. + 14D.; the distance glasses, if placed 20 m/m. further from the eyes than when used for infinity, would do for reading; as the effectivity of a + 11D. lens is increased the required 3D., by moving it forward that distance (see page 57).

If the Aphakia is the result of an operation, there is often a certain amount of Astigmatism present, as well as the degree of Hypermetropia due to the removal of the Crystalline Lens. If so, you correct this in the usual way, as explained in the chapter on that subject—the spherical lens to correct the Aphakia, of course, being placed in the back cell of the trial

frame, as it will be much over 1D. The Astigmatism, when present, is generally "against the rule."

It may be stated here, to advantage, that the visual acuity of aphakic subjects is frequently below normal; so that in many cases it is impossible to obtain anything like a vision of $\frac{6}{6}$. This is accounted for, if we bear in mind that in old age the sight is naturally impaired, and Cataract mostly occurs in elderly people, although it is not unknown in youth. At sixty years of age the visual acuity is about three-quarters, and at eighty years two-thirds, of that which is taken as the standard acuteness of vision of the normal eye.

As an example: You may in some cases be able to bring the vision up to $\frac{6}{18}$ or $\frac{6}{24}$, and no better than this. Although, when compared with the standard vision of an emmetropic eye, this result seems very unsatisfactory, it is a boon to patients with Aphakia – who, without any lenses, are unable to discern even the distance test card, let alone the letters, when situated at about 4·5 metres away.

Also, when testing for reading, you may not be able to make the patient see better than from Jaeger four to nine. So the best advice you can follow in these cases is, not to expect too good results.

CHAPTER XIII.

CYCLOPLEGIA (PARALYSIS OF ACCOMMODATION).

WHEN talking of this condition, it should be understood that it is not a defect or fault in the structure of the eye itself, but in the mechanism of the accommodation. It consists really of the failure of the Ciliary muscle to perform its function; the machinery having in some manner been tampered with, it has run down, and will not regain its former power until this obstacle has been removed.

The accommodation being the only means by which we are able to do any close work if we are emmetropic, it follows that the first symptom of this condition would be manifested when endeavouring to read or sew.

The effect it has upon the sight depends entirely upon the refractive condition of the eye affected. If, for example, the patient was emmetropic, the only inconvenience that would be experienced would be when doing any work close to the eyes; the vision at a distance still remaining unimpaired, because the accommodation plays no part whatever in that performance. But if the patient were hypermetropic, as the accommodation is then brought into action for distance as well as for reading, the vision would be made worse at any distance from the eyes. And in the case of a myope, when the Ciliary muscle is at rest a good deal, being only used when viewing objects within the far point, the patient would only be able to see distinctly at the punctum remotum.

This condition is generally due to the patient being constitutionally run down ; often occurring after any complaint of a lowering character, such as measles, diphtheria, or, in fact, any indisposition which causes general weakness. When this is the case it generally affects both eyes equally.

Sometimes it may be brought on by an accident, such as a blow on one side of the head ; in which case only one eye is usually affected.

It is very seldom that the non-medical refractionist comes across these cases ; but when they present themselves, the correction is, of course, to remove the cause of the inactivity of the Ciliary muscle, whatever that may be. But so as to enable the patient to read, we must prescribe weak convex lenses to do the work of the accommodation for close distances, until the patient has become stronger ; when the Cycloplegia will disappear, and the muscle regain its lost activity.

The removal of the *cause* of the paralysis is generally beyond the province of a refractionist ; so that in many instances the patient must be referred to his family doctor for whatever may be necessary in that respect.

This condition is one of the symptoms of the paralysis of the third nerve which supplies the Internal Rectus, Ciliary muscle, Inferior Rectus, Inferior Oblique, the Iris ; also the muscle which raises the upper lid (called the levator palpebræ), and many others, with the nervous stimulus from the brain necessary to bring them into action. For this reason, when the whole of the third nerve is affected, external Strabismus and drooping of the upper lid (Ptosis) may occur. There may also be a difficulty in moving the eyeball inwards and outwards.

The correction is the *weakest* convex lens which enables the patient to read in comfort. This is usually about + 3D. ; as the average reading distance is thirty-three centimetres.

If the patient is emmetropic, then the glasses will only be given as a temporary expedient, and may be discarded entirely when the patient recuperates his strength. Of course, if

patient was previously ametropic, then the + 3D. for reading must be added to his usual distance correction, and after the Cycloplegia has passed away, he would return to the glasses previously given for his Ametropia.

Symptoms.—If a patient, under about forty years of age, can see only the largest types on the reading card, but at a distance, with the naked eye, can read $\frac{6}{6}$, and a weak plus lens makes vision worse—he has Paralysis of the Accommodation.

Photophobia (intolerance of light), Asthenopia (weakness of the eyes), and dilatation of the pupil often accompany this defect.

Naturally, the most prominent symptom is the loss of accommodation, consistent with the patient's age and refractive condition.

In conclusion, it may be stated that coloured glasses should be given to correct the Photophobia—they should be of as light a tint as possible to serve the purpose; and should be left off as the patient is again able to bring his accommodation into play.

SPASM OF ACCOMMODATION.

This is exactly the opposite condition to the Paralysis just explained. Spasm of the accommodation is as diverse from Cycloplegia as Hypermetropia is from Myopia. It consists of an over-action or contraction of the Ciliary muscle; which is sometimes of such an extent as to disguise the real condition of the refraction—also in some cases the Spasm may be of so great an amount as to simulate Myopia, even if the patient's condition is really one of Hypermetropia. Hence it is also called Apparent or Simulated Myopia. It is of two kinds; the first, and most troublesome, being called *Tonic Spasm.*

This may be found in any patient up to about forty years of age; after which, the accommodation is generally too weak to be affected to this degree. Tonic Spasm is of a permanent nature; so much so that in many cases it is necessary to use a

cycloplegic before it is possible to coax the Ciliary muscle to relax fully. This is the variety usually referred to when the expression "Spasm of Accommodation" is used.

Clonic Spasm is the second variety; but it only occurs when the patient is using his eyes, and is not permanent like the "Tonic Spasm." This may be found in people as old as fifty or even fifty-five years of age; and is quite as troublesome in testing as the former kind. It is often found, in this variety of Spasm of Accommodation, that the vision alters from one minute to another. Patient's answers are also often very misleading; as one moment, with a certain glass before the eye, patient may see perfectly, and then suddenly inform you that he can no longer see through the lens.

Spasm of Accommodation, either Tonic or Clonic, affects both eyes together; and is due to an abnormal activity of the muscles of accommodation, which is brought on in many cases by sheer nervousness—being present, in the majority of cases, in patients of an excitable and nervous disposition.

When this condition is present in young people, it is nearly always a sign of Hypermetropia; as in this defect the Ciliary muscle is kept constantly in a state of excitation, unless it be corrected with suitable glasses—although Spasm may occur in Emmetropia, or even, in some rare cases, in myopic patients.

If the patient is an emmetrope, the condition simulates Myopia; and there is the possibility unless great care is taken, of prescribing concave lenses.

If it occurs in a myopic patient, it would increase the apparent amount of the defect; and in the event of Spasm occurring in a hypermetropic patient, it would either disguise part or the whole of this defect; or in some cases overcome the Hypermetropia entirely, making the patient appear as if he was short-sighted.

This last is met with especially in young children. The reason why, in a previous chapter, it was advised not to have

any one in the testing-room besides the patient and operator, was because Spasm of Accommodation is due to extreme excitability, and if there were anyone watching the procedure of testing, the patient might, through nervousness, involuntarily exert his accommodation excessively—in this way producing the Spasm.

The most prominent symptoms are the following:—

Epiphoria (overflow of tears), Photophobia, contraction of the pupil (in real Myopia the pupil is usually widely dilated), congestion of the eyes, also pain. The distant vision is, of course, impaired; which makes the state of affairs appear to be myopic.

Spasm of the Ciliary muscle is also recognised by the fact that the accommodation is not so great as the age and apparent refractive condition would indicate. In other words, the near point will be further away from the eyes than it should be if the apparent anomaly of refraction was accurately estimated. In order to illustrate this, let us take the following example:—

A girl of fifteen years sees $\frac{6}{18}$ with the naked eye, and with -2D. vision equals $\frac{6}{6}$; but on measuring the near point, without any lenses before the eyes, we find that it is only at ten centimetres from the eyes whereas, if the patient was really myopic 2D. at this age, she should read at seven centimetres from the eyes; which shows $\frac{100}{10} = 10$D. of accommodation. This is a deficiency of 2D., when compared with the normal amount at this age; therefore the patient is hypermetropic 2D. (Refer to Table of Amplitude of Accommodation, p. 81.)

Another way by which one may detect Spasm is to listen to the patient's complaint about his eyes; when you will probably hear that the sight has only been bad a short time—in fact, the defect came on quite suddenly. This at once leads you to suspect the nature of the trouble, as Myopia, of course, does not come on suddenly, but is of gradual growth.

As is well known by my readers, convex lenses constantly encourage the accommodation to relax. It is for this reason we use the strong convex lens to tie up or paralyse the accommodation, in testing for Hypermetropia. The correction for Spasm of Accommodation is a convex lens; the correction for reading must necessarily be stronger than those prescribed for distance.

The wearing of the convex glasses will make the vision worse for the time, and patient may not want to wear them; but you must insist upon their constant use, both for reading and distance.

A moderately strong pair should be given for reading, and a weaker one for distance. Explain to your patient the condition of the eyes, and that by wearing the convex glasses the accommodation will gradually become relaxed; and that if he perseveres, he will soon be able to read normally.

Never, by any chance, when a child suddenly notices that he is unable to see at a distance, give him a concave lens simply for the reason that he sees better with it—in fact, with all young children, if the vision is markedly improved by weak concave glasses, always prescribe convex lenses to be worn for a couple of weeks. Then, if by that time vision is not improved, and patient still cannot see through them, you will be pretty safe in resorting to minus lenses. But in most cases, when the patient returns, it will be with the tale that after wearing the glasses, the vision began to improve; showing the presence of Hypermetropia.

To illustrate this, take the following case, which is one of the many similar cases I have met with in my own experience:

A young boy was brought to me by his mother, who complained of the lad being unable to distinguish the writing on the blackboard at school, and other symptoms of short sight. On testing, I found the visual acuity without glasses was $\frac{3}{18}$; and that a $-1{\cdot}50$ lens brought the vision up to $\frac{6}{9}$. This weak minus giving such a great improvement at once suggested

Spasm of Accommodation to me; and on measuring the near point, I found Hypermetropia present to the extent of 2D., and prescribed in consequence convex lenses. The result was that the boy returned after wearing the correction some little time; when I was able to increase the amount of the correction, which still rendered a vision of $\frac{3}{3}$—although at first patient could only see very badly with the plus glasses.

If a patient has very poor distant vision, and is able to read the smallest letters on the reading type; but on measuring the accommodation it is found that he possesses less than his age and apparent refractive condition would point to, it is certain to be a case of Spasm of Accommodation.

Thus it is seen that, by measuring the near point, and finding that further from the eyes than it should be, we are able to differentiate between Simulated and Real Myopia.

It is therefore always advisable to have at hand a near point measure; or failing this, an ordinary tape measure and reading card, using the smallest type, will suffice for the purpose.

It is to prevent the tendency to Spasm of Accommodation that the "paralysing" method of testing for Hypermetropia should be used in all cases, except, perhaps, in those of elderly people, whose accommodation is very much weakened, or entirely absent.

CHAPTER XIV.

THE ADAPTATION OF FRAMES.

Up to the present we have been studying only how to obtain the necessary lens, or combination of lenses, to correct our patient's visual deficiency; and how to remedy the evil effects attendant on Ametropia in its different varieties, by the proper adaptation of lenses. It is now incumbent upon us to devote some thought to another equally important question—that is, how to place before the eyes, in the best manner, the correcting glasses found necessary.

It is as important that the correction be placed accurately before the eyes, so that the patient looks through the centres of the lenses, as it is to prescribe the correct glass for the optical defect. In fact, unless they are so placed, the glasses would probably have a detrimental, instead of a beneficial effect upon the patient's sight.

The lenses are placed before the patient's eyes, and kept in position by means of frames so made that the glasses may be screwed into them and held firmly in position. The several patterns of frames, and their special advantages, will be fully described later on.

The different materials of which frames may be made are many, the four principal being the following:—

Gold.—This is perhaps the best and the most expensive material for frames to be made of. The fineness should be from

nine to fourteen carats, as anything less pure than this will make a disagreeable black mark upon the skin, and any finer alloy than this would be too soft.

Gold-filled is a very satisfactory material; and, indeed, it would be difficult to find a better, when the gold-filled is of the very best make. This material is composed of a seamless tube of gold, drawn over a firm base metal; this gives the material a hardness which makes it more satisfactory than the solid gold. This material does not make any objectionable mark upon the skin, also the cost of such a frame is very reasonable; and lastly, provided you have the finest quality, it keeps its colour.

Aluminene is a well-known composition, the especial advantage of which is that it will neither tarnish nor rust—which is most important, especially in spectacle frames. In eyeglasses, it is not so essential that they be made of a non-rusting metal, as they do not come in contact with the face so much, and consequently are not acted upon by the perspiration to such an extent as spectacle frames would be.

Nickelled steel forms a very good material for frames, as the metal is inexpensive; but the disadvantage is that they are liable to rust so easily. This is most noticeable when the frames are worn constantly—for occasional use they are not, of course, so objectionable.

Silver and *solid nickel* are much too soft to be used with advantage for making spectacle frames.

Aluminium would make an excellent material, only, unfortunately, we know at present nothing which will solder it satisfactorily; so that we are debarred from using it. Otherwise, its lightness, non-rusting properties, and cheapness would make it an admirable metal for our purpose.

Frames may be divided into two distinct forms. Those which keep on by means of sides or arms, extending along the temple to behind the ears, are called "spectacle frames"; whilst those which maintain their position by means of a spring which keeps them in contact with the nose of the wearer are

called "eyeglasses"; or, to use the French expression, "pince-nez."

By far the most comfortable and accurate method of fitting a patient's face is by means of spectacles; but for elegance and comeliness the eyeglasses are certainly to be preferred, as also for the ease and rapidity with which they may be removed or placed in position.

In some cases, of course, only spectacles should be allowed—for example, in Astigmatism, especially when the cylindrical axes are oblique. Otherwise, when possible, I advise my readers to allow their patients' wishes to be considered in the selection of a frame as much as possible.

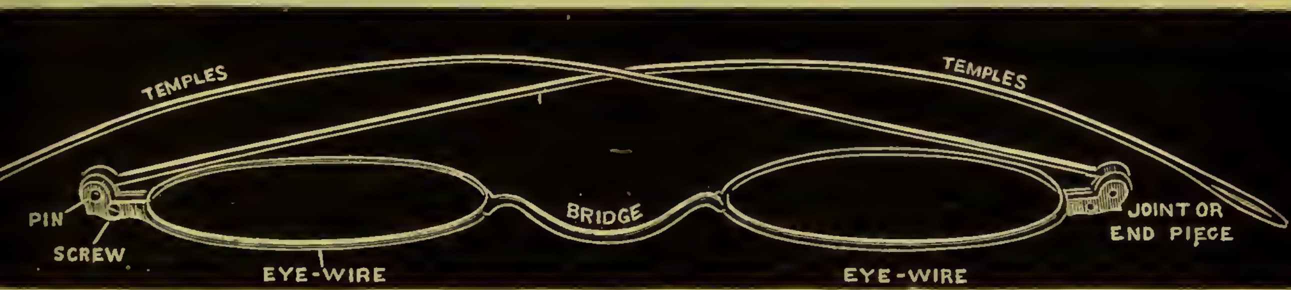


Fig. XCVI.

A spectacle frame is made up of several different parts; and a glance at the above illustration will show the position and name of each. These parts are briefly:—

Two eye-wires, one bridge, two end-pieces or joints, two temples or sides, two screws, and two pins.

The *eye-wires* are for holding the lenses; being grooved, the lenses fit into these, and can be fastened in position by tightening the screws. In order to place a lens in the frame, it is necessary only to turn the screw about four times, when the joints of the eye-wire will part slightly, and you are then able to spring your lens into position in the grooved wire.

The *end-pieces* or *joints* are where the temples fit over the pins. To remove a temple, you must turn the screw entirely

out, so that the joints may come quite apart; when you can then lift the side off the pin.

The *sides*, it is unnecessary to add, are for holding the frame on the face of the wearer.

The component parts of an eyeglass are thirteen in number, if we include both the eye-wires, the two guards, and so forth. The different sections are only eight, as follows (see also illustration):—

The *eye-wire*, which is for the same purpose as in a spectacle frame.

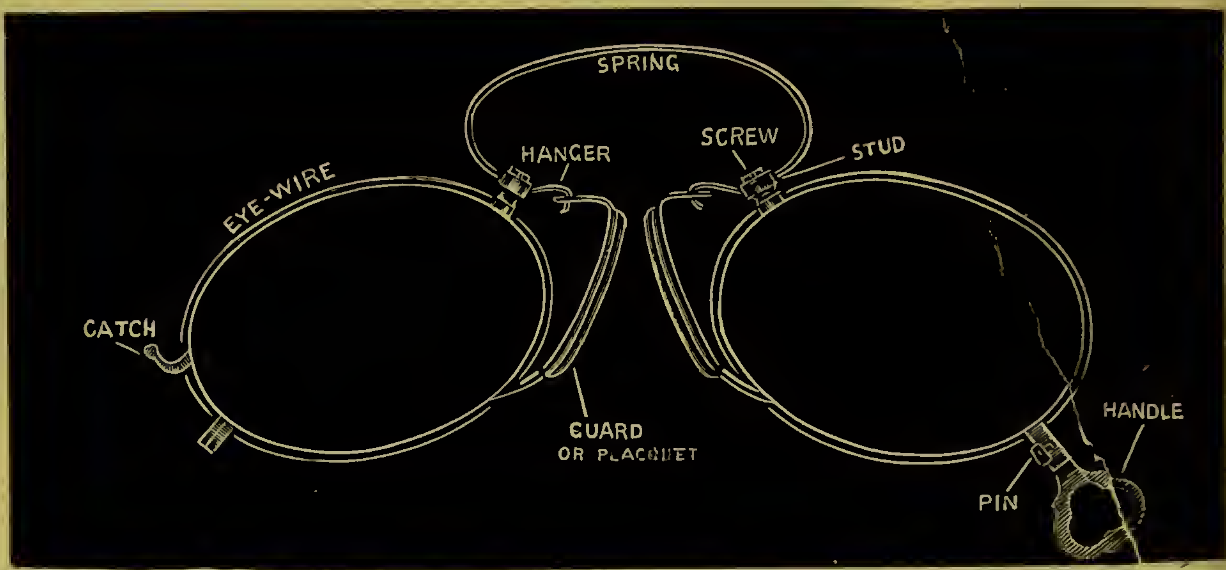


Fig. XCVII.

The *spring*, which enables the frame to retain its position, by pressing the guards or placquets against the side of the nose.

The *hanger* is a little projecting piece to which the guards are attached. This, as well as the spring, fits into the stud; and they are both fastened by means of a small screw.

Now that we know the names and purposes of the several portions of a frame, we will consider the different varieties of spectacle frames; leaving the eyeglasses alone for a while.

Spectacles are of two kinds. The first are those with straight temples or sides, and are called "S.S.," meaning "straight sides." The others are those with curled temples,

and are termed "R.B.," which stands for "riding bow"—this phrase is an American expression, in place of "curl side." It is well here to mention that there are two forms of curl sides; the single wire and the twisted wire temple. The best of the latter are composed of eight wires twisted round a centre one, so that they are very soft and flexible, and do not make a mark behind the ears, as the single wire might do—which is a distinct advantage. These twisted temples are called "cable"; so that an "R.B. cable" would be a spectacle frame with twisted wire temples. "R.B." frames should be given for constant use, or when glasses are necessary for out of doors—as the cannot slip down from the proper position.

The "S.S." frames are for reading, as they are more easily put on or off, and can be placed lower down on the face, which is necessary when reading. It is best, when these frames are used only for reading, that they be angled at about 15°.

There is also a varied assortment of *bridges* in spectacle frames.

The "C" or "crank" bridge (A, Fig. XCVIII.) is given for reading or close work.

The "hoop" or "arch" bridge (B, Fig. XCVIII.) is for any one with a narrow distance between the eyes, and who yet has a fairly wide nose. This wide bridge is obtained with the hoop pattern, although the distance between the eyes can be narrow. This measurement is obtained by having no joints, as there are in the "C" bridge (+ + in A, Fig. XCVIII.); but the hoop is attached directly to the eye-wires.

The "saddle" or "W" bridge (C, Fig. XCVIII.) is the acme of perfection, so far as fit is concerned. It shapes round the nose exactly, and possesses the additional advantage over the other forms that it is easily adjusted to any width by bending the shanks or arms of the bridge with pliers. This bridge is given for constant use, and for wearing out of doors; it is also useful for reading, when a special nose measurement is required.

The "snake" forms another very useful bridge (D, Fig. XCVIII.). It resembles the saddle bridge very much, the difference being that the shanks project straight backward from the eye-wire, instead of declining downwards as they do in the "W" bridge. These are valuable for fitting children or a

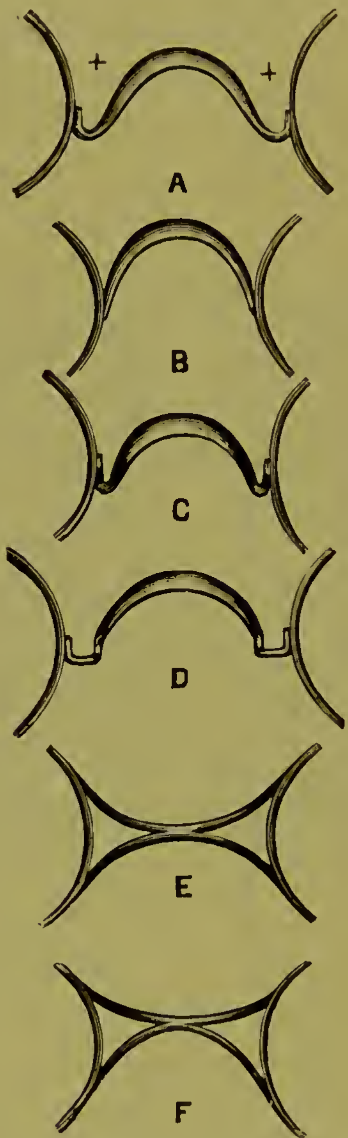


FIG. XCVIII.

patient with a flat nose or very long eyelashes, when you wish to throw the lenses forward from the eyes somewhat.

The "X" bridge (E, Fig. XCVIII.) is convenient when the patient has only one eye, and a different correction is necessary for reading and distance, because it obviates the necessity of two pairs of frames, as the reading glass is placed before the blind eye when the patient is looking at a distance; and when

wishing to read he simply turns his frame over, and places the distance glass in front of the useless eye. This end is also attained by using frames with reversible sides. These frames are constructed in the same manner as the ordinary ones, only that the joint works on a pivot, so that the temples may be turned either forward or backward. The bridge, of course, in this frame would be either an "X" or "K." This latter bridge

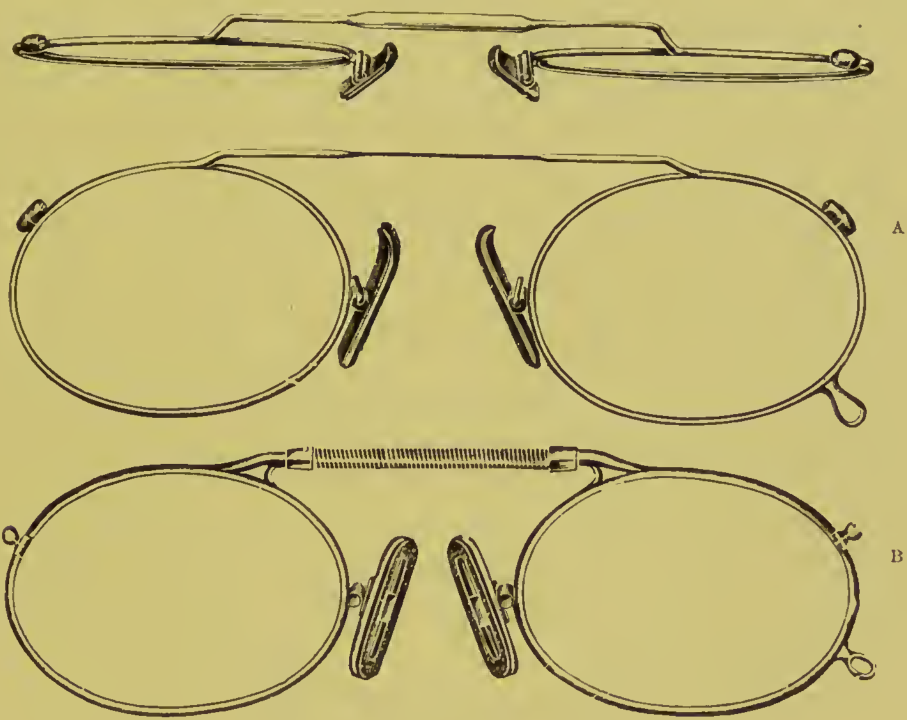


FIG. XCIX.
(Both these are made by the Anglo-American Optical Co., London).

resembles the "X," except that the lower portion is more deeply curved than the upper (F, in Fig. XCVIII.).

Eyeglasses, like spectacles, are of two forms—those which fold up, called "Folders," and those which do not fold, called "Astigs," as these are the only patterns of eyeglasses which may be worn by an astigmatic patient.

If folders are given in cases where this defect exists, the axis of the correcting cylinder is seldom before the eye twice in the same meridian. Spherical lenses may be glazed or fitted into any pattern of spectacle or eyeglass; there are no restrictions as to the kind of frame to be worn where they are required.

"Astigs" are of two kinds; those having a spiral spring encircling the bars, which owing to its outward pressure draws the guards together and makes them grip the nose; and springless ones—commonly termed "clips." The obvious advantage of the latter is, that the continual "drawing" of the spiral spring is absent; which renders them less liable to mark the nose. A little more attention is required to fit them; but since a variety of pupillary distances are always obtainable, this entails really very little trouble, and the extra care necessary is more than compensated for by the increased comfort to the wearer. (The regular "Astig," and a popular form of springless clip are shown in Fig. XCIX., A and B).

Spectacles or eyeglasses should be placed as near as possible to the eyes, the lashes just escaping the lenses, which distance is usually about twelve millimetres, or half an inch, in front of the Cornea. There are many different kinds of the offset guard, all supposed to possess an advantage over the others, and some are really useful in particular cases. Illustration Fig. C. shows a few different patterns that may be considered essential for the conditions described below; and will be found to answer in the great majority of cases.

The guard A is the usual offset pattern, being set at an angle of about 45° with the front of the frame, and so grips well back; thus ensuring a firm hold.

B it will be noticed, is similar to A, only more upright, and therefore suitable for less prominent noses.

Both A and B are fitted to "clips" intended for constant wear, or for distance. If the frames are only to be used for reading, then C is the guard to have, as the arm is attached below the centre, and so allows the lenses to set lower; which is necessary for reading, since the eyes are then naturally turned downwards.

The guard introduced of late years, and possessing the most improvements over old styles, is undoubtedly the so-called "Stanley Guard" (D, Fig. C.). It is oval in shape, hollow in the centre, so that it firmly grasps the nose and cannot easily

slip from its position. The particular point in which it differs from all other styles (and wherein lies its great advantage), is that the guard has both a *lateral* and *vertical* movement, so that if the sides of the nose are not symmetrical (as is frequently the case), these guards adapt themselves independently of each other, their surfaces assuming different planes; thus adjusting themselves to the shape of the nose, and so allow the frame to remain perfectly straight. This pattern of guard is the best for all *rigid-bar* eyeglasses.

E represents the guard common to most "astigs" and springless horizontal-bar clips.

There are numerous other patterns of guards, but their utility must be left to the judgment of the refractionist. The foregoing are those recommended, and indeed will be found to meet almost all requirements.

In addition to the kinds of frames just described, there is another form, known as "Frameless" spectacles and eyeglasses. In these, the eye-wire which encloses the lenses is entirely dispensed with (hence the appellation); there being, instead, two small holes drilled in the lenses at the outer and inner ends

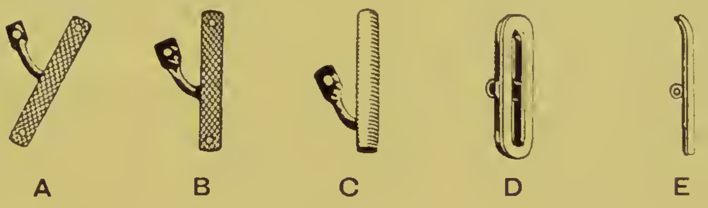


FIG. C.

of them, by which the temples and bridge are secured in position by means of a small screw. The advantages of this form are, that they are less conspicuous, and also lighter than the ordinary frames. They should never be given to children, as they break easily, being slightly weakened where the holes are drilled. Also, if they fall, the lenses are liable to break, having no protection. The lenses used should not have polished edges, but should be dull, so as to prevent any disagreeable reflection of the light. As far as appearance is concerned, this

style of frame leaves nothing to be wished for, and it is used universally in America, but in this country its advantages have yet to be fully appreciated; although they are steadily increasing in popularity.

Having now fully discussed the varieties of frames at our disposal, we must pay attention to the all-important question of fitting our patient with a frame that answers all the necessary details requisite to a perfect fit.

Unless the frame is perfectly adjusted, to the wearer's face, the beneficial effect intended by prescribing the correction of the visual defect may be entirely defeated, and some fresh source of trouble may result.

The most exact method of fitting a face is certainly with spectacles. When eyeglasses of any pattern are used, we must not expect such an accurate fit; the frames adapt themselves more or less to the face. Personally, I recommend my patients to have spectacles for constant use, and to have eyeglasses for occasional wear, when they object to wearing the spectacles out of doors.

The accurate position for a frame is that when before the eyes the visual axes correspond exactly to the optical centres of the lenses.

The visual axis is an imaginary line, drawn from the object under observation to the retinal image.

The optical centre of a perfectly ground lens corresponds to its geometrical centre. Whether this is so or not can be easily ascertained in the manner that was described in Chapter III.

Before going any further into the subject under discussion, it is necessary for the reader to understand the meanings and abbreviations of the terms used for the several measurements of the face.

"P.D." means the inter-pupillary distance; that is, the distance between the centre of one pupil and the centre of the other. This measurement varies from fifty millimetres to sixty-seven millimetres, the average width being sixty millimetres (or,

to have it in inches, from two inches to two and five-eighths inches, the average width being two and three-eighths inches).

"F.W." is the facial width; that is, the distance between the two temples. When taking this measurement with a rule, it is necessary to make an allowance of six millimetres, or a quarter of an inch, because the temples are usually not so wide as the top of the cheek-bone.

The height of the bridge is the distance of the bridge above or below an imaginary horizontal line connecting the geometrical centres of the lenses.

The width of the base of the nose is also a necessary measurement.

The set of the bridge is another essential detail to be considered when fitting a frame; it must be noticed whether

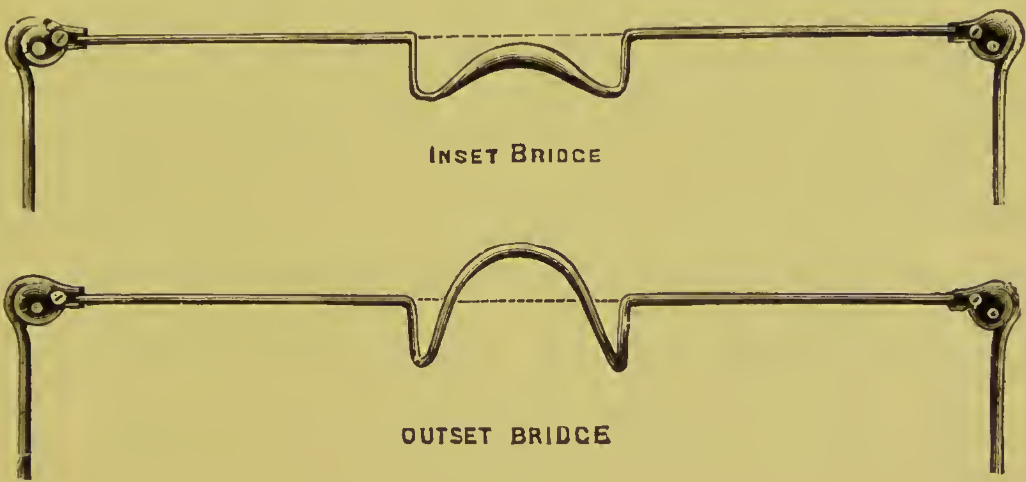


FIG. CI.

the bridge is to be set inwards or outwards. The "inset" and "outset" of the bridge of a frame are measured from the anterior plane of the lenses. In the first instance, measure how far the *middle of the spread* of the bridge is behind the *front surface of the lenses*; and in the latter, how far this portion of the bridge protrudes in front of the same. An inset bridge is necessary when the lenses are required to be placed away from the eyes; and the bridge must be outset when the lenses are to be put close up to the eyes.

The last measurement necessary is the distance from the patient's temple to the back of the ear, when "R.B." sides are wanted. When "S.S." are worn, this measurement is unnecessary; but it is well for the sides to be fully long.

It is never advisable to take the measurements of your patient's face with a rule, and ascertain the dimensions for your frame in this way. But should this be done, it must be remembered that one eye is sometimes closer to the nose than the other; consequently the distance of each eye from the nose should be ascertained separately. The most satisfactory method is to possess a set of "Prescription Frames" made in all measurements, and fit your patient with these until you obtain one that answers perfectly in all particulars; or should any alteration be necessary, it is easily noted when the frame is on the face, and should be written down at the time.

An ingenious arrangement of these frames, whereby spectacle frame fitting is rendered very simple, is as follows:—[1]

The 'set' consists of 36 frames supplied in a case, and arranged in the order shown in the accompanying diagram. On referring to this, it will be observed that the first dozen frames, Nos. 1—12, are all flush (that is, the top of the bridge is in the same plane as the lenses); Nos. 13—24 are all 'outset'; and Nos. 25—36 are all 'inset'; these three sets of frames being arranged vertically. Looking at the frames horizontally, it will be seen that the top dozen all have a pupillary distance of $2\frac{1}{4}$ inches; the second dozen have pupillary distances of $2\frac{3}{8}$ inches; and the last twelve a pupillary distance of $2\frac{1}{2}$ inches. The figures on the right side show the height of the bridge of each frame in that line.

A little practice will soon render one expert at finding any frame required; and moreover, one soon remembers the arrangement of the frames without reference to the chart (supplied with each case), and so at a glance picks out one of any desired

[1] (I am indebted to the Anglo-American Optical Company, of Hatton Garden, for particulars of this Prescription Set which was made at the suggestion of Dr. Murtaugh Houghton).

P.D.	FLUSH.	OUTSET.	INSET.	H.B.
	1 - - -	13 - - -	25 - - -	0
$2\frac{1}{4}$	- 2 - -	- 14 - -	- 26 - -	$\frac{1}{8} = 3$ m.m.
57 m.m.	- - 3 -	- - 15 -	- - 27 -	$\frac{1}{4} = 6$ m.m.
	- - - 4	- - - 16	- - - 28	$\frac{3}{8} = 10$ m.m.
	5 - - -	17 - - -	29 - - -	0
$2\frac{3}{8}$	- 6 - -	- 18 - -	- 30 - -	$\frac{1}{8} = 3$ m.m.
60 m.m.	- - 7 -	- - 19 -	- - 31 -	$\frac{1}{4} = 6$ m.m.
	- - - 8	- - - 20	- - - 32	$\frac{3}{8} = 10$ m.m.
	9 - - -	21 - - -	33 - - -	0
$2\frac{1}{2}$	- 10 - -	- 22 - -	- 34 - -	$\frac{1}{8} = 3$ m.m.
63 m.m.	- - 11 -	- - 23 -	- - 35 -	$\frac{1}{4} = 6$ m.m.
	- - - 12	- - - 24	- - - 36	$\frac{3}{8} = 10$ m.m.
P.D.	FLUSH.	OUTSET.	INSET.	H.B.

(Registered.) Fig. CII.

measurement, as the spectacles correspond exactly in their arrangement with the Nos. shown on the chart. To illustrate the use of these, take the following example:—

From our trial frame we see that the pupillary distance necessary is $2\frac{3}{8}$ inches; and on looking at our patient's face we can judge easily whether the bridge is to be flush, outset or inset. Let us suppose it needs to be outset; then, on reference to the chart, we know that our frame will be either No. 17, 18, 19 or 20; as only these four numbers have a pupillary distance of $2\frac{3}{8}''$ with an outset bridge. Again looking at our patient we guess the height of bridge to be $\frac{1}{4}$-inch, and consequently try on

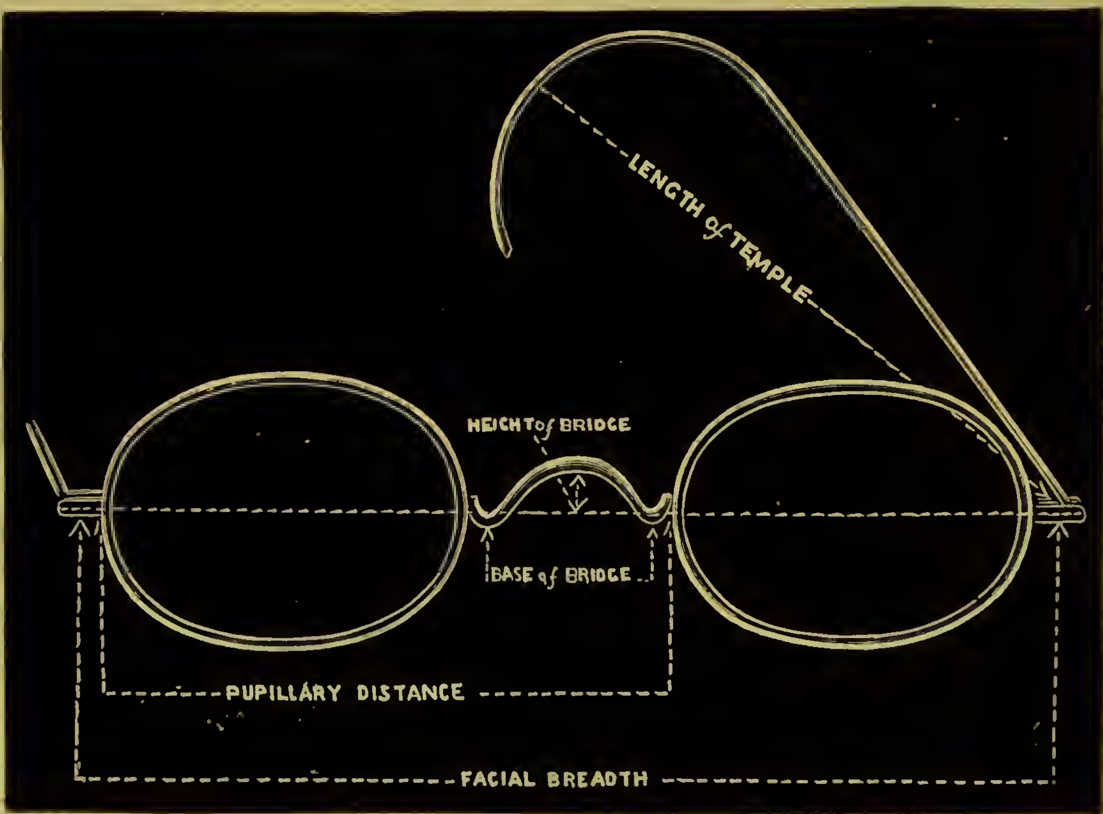


Fig. CIII.

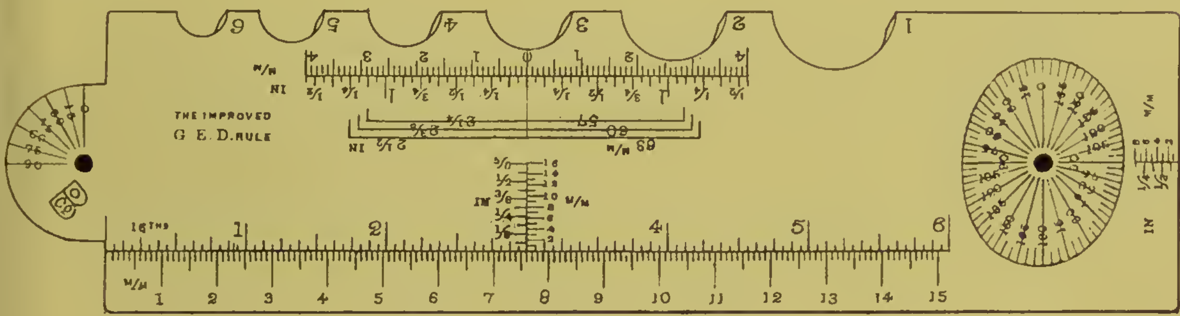
frame No. 19. If this is not correct, the frame must of necessity be 18 or 20; the first being lower and the latter higher than the frame you have just fitted on the patient's face, other particulars being identical. Thus it is seen that only two frames need be handled, to fit almost any person.

In cut Fig. CIII. you will see the dimensions given, as they apply to *frames*. (It will be noticed that when measuring the *facial width* of a frame the measurement includes the joints).

When measuring an "R.B." temple, you take the length from the joint to the greatest curve of the bend; and when taking the "P.D." of a spectacle frame, the measurement is taken from the outer end of one eye-wire to a corresponding part of the other eye (see Fig. CIII.)

A useful rule for taking these various measurements is shown in the accompanying illustrations, and the directions for using same detailed here:—

To obtain the facial width of a frame (F.W.), the frame



Front of "G.E.D." Improved Rule.
FIG. CIV.

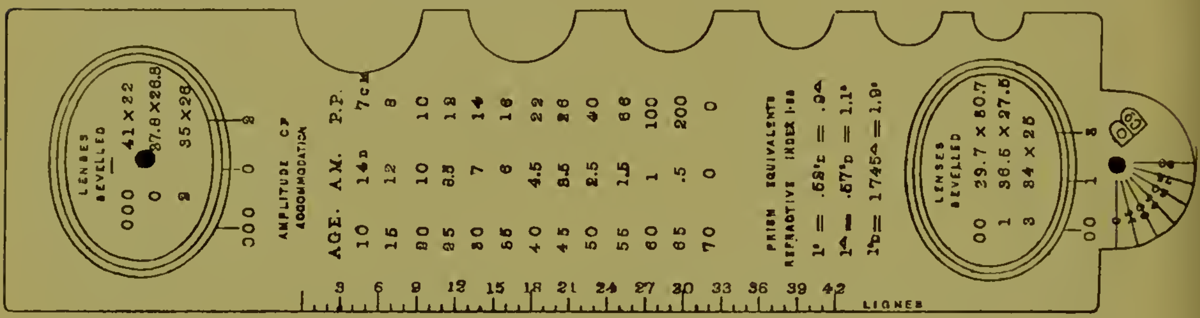
should be held *inverted* in the *left hand*, and the rule in the right. Place the face of the rule against the surface of the lenses or eye-wires, allowing it to rest on the under sides of the joints, when you can easily read off the facial width of the spectacle by sliding the rule to the right until the commencement of the millimetre scale is just at the outer edge of the left joint in the present position of the frame. The reading is taken at the outer edge of the right joint.

To ascertain the pupillary distance of a frame (P.D.), both the rule and frame should be in the same position as above; only slide the rule to the right a little more, so that the commencement of the scale is at the outer edge of the left eye-wire (looking at the frame in its present inverted position).

The pupillary distance can now be read off the *inner* edge of the other eye-wire.

To measure the height of a bridge of a spectacle (H.B.), place the frame, front downwards, on the rule, so that the centres of the joints are on the long horizontal line dividing the inch and millimetre scales, and the centre of the bridge is on the small perpendicular line of the vertical scale. The height of the bridge is now easily seen; the measurement should be taken from the centre of that edge of the bridge which is against the rule.

The projection of a bridge (P.B.), is taken from a scale at the right end of the rule. If the projection is outward, hold



Reverse side of "G.E.D." Rule.

Fig. CV.

the frame *inverted* in the *left hand*, and place the end of the rule against the top (when in an upright position) half of the eye-wires, so that the centre of the arch of the bridge is against the vertical line of the scale. The projection is measured from the middle of the spread of the bridge. The inset of a bridge is taken in the same manner; only place the rule against the back surface of the lenses. An allowance of 1 m/m. must be added to this measurement, to make up for the thickness of the eye-wire of the frame, as the "inset" of a bridge is really taken from the front surface of the lenses.

The size "eye" of a frame can be ascertained by placing the eye-wire of the spectacle, face downwards, over the figure on the reverse side of this rule (Fig. CV.).

The exact direction of the axis of any cylindrical lens can be obtained by marking the direction of the axis on the lens with ink or a "grease" pencil, and placing the lens, *front* surface *upwards*, on the protractor. The horizontal line should be exactly across the centre of the lens, and the point from which the lines of the scale are proceeding should be at the optic centre, when the line drawn on the lens, indicating the axis, will fall on one of the meridians, and its direction can be noted.

To obtain the pupillary distance of a patient, place the curve over which is marked "O," on one side of the rule, upon the bridge of the nose, and tell patient to look at any distant object directly in front of him, when the distance of *each eye separately* from the centre of the nose can be seen from the *lower scale;* if the total distance between the eyes is required, this is read from the *top scale.* If the pupillary distance is being taken for reading, let the patient look at you during the time you are taking the measurement. All the above measurements of frames or of the face can be taken either in *inches or in millimetres;* both systems being shown.

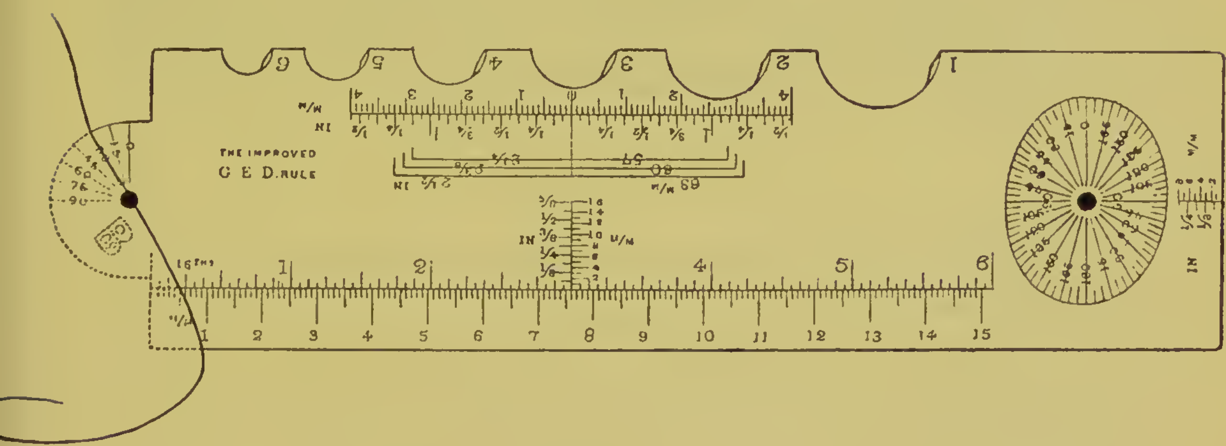


FIG. CVI.

The curves cut out of the side of the rule, and numbered from 1 to 6, give the various "spreads"; and the nose to be measured should have these fitted on it until one is found which exactly follows the contour of the nose-bridge, and the

R

number noted on your order form. The small quadrant scale projecting from one end of the rule is to judge the inclination of the top of the nose from the vertical (upon which, of course, depends the angle of the spectacle bridge). Hold the rule horizontally against one side of the nose, and from *the other side* you can readily see at what angle the nose projects; such angle being taken from the vertical direction. (See Fig. CVI.).

The science of frame-fitting (for it is a science to do so accurately) is summed up in a few words.

See that the pupils are exactly in the centres of the lenses. When taking this measurement, if the frames are to be worn for distance, direct patient to fix some distant object; but when the frames are for reading purposes, it is well for him to direct his attention to a near point, as, when reading, the eyes converge, and the pupils are thereby brought nearer together. This is a reason why bi-focal lenses are rarely very satisfactory,

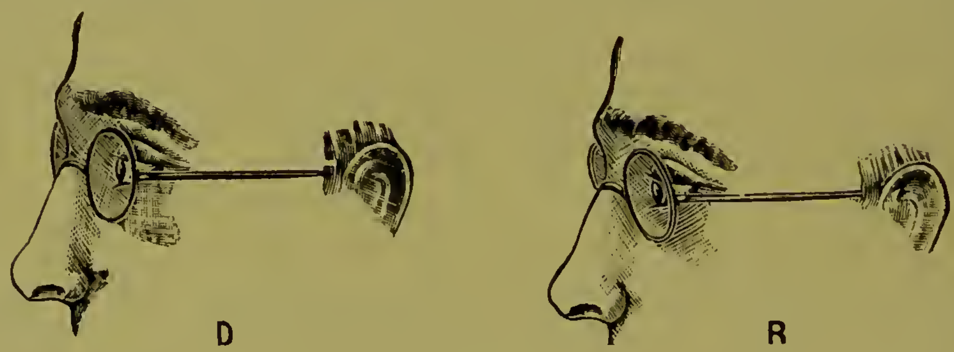


Fig. CVII.

unless the segments are placed a trifle inwards—which will be explained later.

See that the bridge sits well on the nose. The lenses must be as near as possible to the eyes, so long as they do not interfere with the movements of the lashes. If they are too far from the eyes, a convex lens is stronger than when placed at the proper distance; and conversely, a concave glass is weaker when placed farther away from the eye. This is the explanation of the fact that presbyopes who have had their glasses for some years place their spectacles far down on the

nose. Doubtless, when they first wore these glasses, the position was close to the eyes; and gradually, as they became weaker, the frames are slipped down the nose, and in this way the glasses are increased in power—the lenses, of course, being convex; and thus the patient obtains an artificial accommodation.

Notice that the sides of the frames do not press against the patient's temples. When they are for distance, the lenses should be set perfectly vertical before the eyes. If the frames are intended for reading, they should be angled sufficiently to enable the patient to read without bending his head; and also that he should be unable to see the lower eye-wire of the frame (see Fig. CVII. D and E).

The angle of the lenses should be such that, when looking through them, the visual axes are perpendicular to the lens surfaces; because, if looked through obliquely, a spherical lens

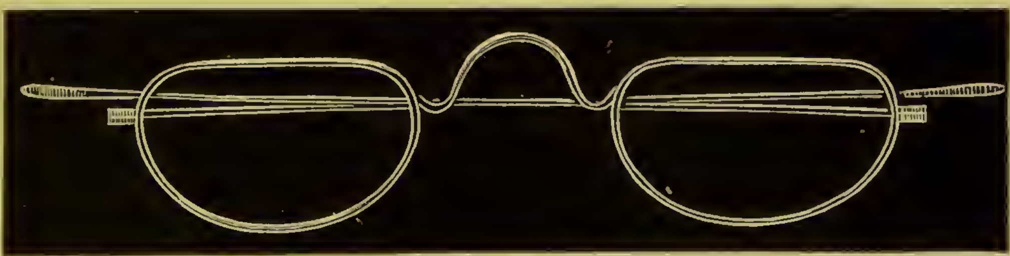


FIG. CVIII.—PANTOSCOPIC SPECTACLE.

has the effect of a sphero-cylinder with the axis parallel to the axis on which the lens is tilted. And in a like manner the effect of a compound lens would be altered.

Glasses to be worn constantly are more satisfactory when fitted into a frame of some non-rusting material.

Spectacles are by far the most comfortable, and by the majority of patients are preferred when reading; but when walking or visiting, as the case may be, the more elegant eyeglasses are the favourites. However, they all pinch the nose, to a greater or lesser extent, as they must necessarily hold on to something in order to keep on the face; but this

inconvenience is put up with for the sake of appearance—such is the penalty of vanity!

Where spectacles are required for reading only, in such cases as Presbyopia without complications, frames are made with the eye-wire of a half-oval shape, so that the tops are flat, which allows the wearer to look over the lenses when looking at a distant object. These frames are called "pantoscopic"; and they are especially useful to public speakers, who have to look at their notes one minute, and the next at their audience.

For those patients who require different lenses for distance and reading, and do not wish to have the trouble of changing from one pair of spectacles to the other, the frames may be fitted with what are known as "bi-focal" lenses. These are, as their name applies, made with two different foci in each glass; the lower part being for reading and the upper portion for distance. These lenses were first invented by Benjamin

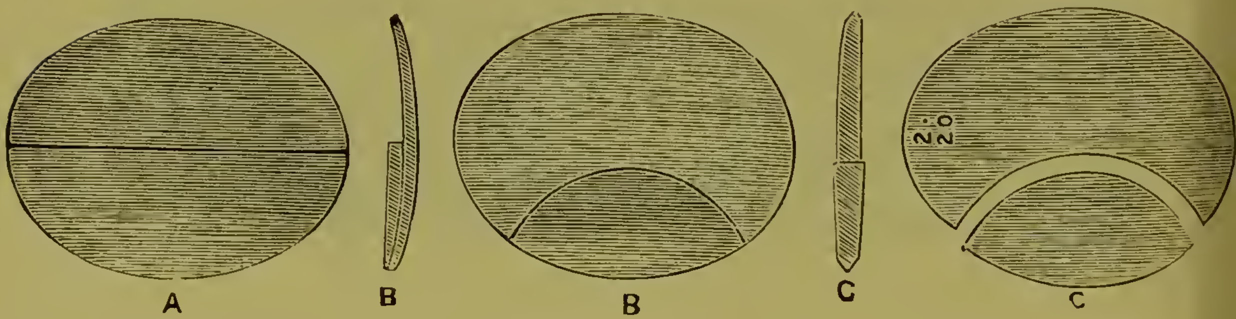


Fig. CIX.

Franklin, nearly one hundred and fifty years ago; and the particular pattern which he brought into use are termed the "split bi-focal" (A, Fig. CIX.). This is now out of date, having one great disadvantage; that the line of junction of the two lenses is in the line of direct vision, and is therefore apt to interfere with the field of vision.

There are several patterns of bi-focal lenses, the best, I consider, being the "cemented"—which consist of the ordinary distance lens, on the lower portion of which is cemented (with Canada balsam) a small lens wafer, whose strength, added to

that of the distance glass, equals the amount required for reading (B, Fig. CIX.).

Another good form of bi-focal is the "Perfection." This is made up of two distinct pieces; the lower segment so constructed that it fits easily into the curve of the upper lens. The advantage possessed by this form over the cemented bi-focal is that the lower segments are interchangeable; so that a greater selection can be had with fewer lenses. But the connecting line is more conspicuous in this form than in the other, and, therefore, not quite so satisfactory for use, unless they are grooved; that is to say, unless the inner edge of the segment is grooved into the upper part. The difficulty in prescribing these is, that there are so few optical houses who can turn them out satisfactorily. This form (only not grooved) is illustrated in Fig. CIX., C.

In the last two varieties the line of junction of the segment is below the horizontal line connecting the geometrical centres of the lenses, and is consequently not in the path of direct vision.

Bi-focal lenses certainly obviate the trouble incident upon frequently changing from the near to the distance glass; but they all have one inconvenience—that is, in walking, the patient is apt to look through the lower part of the lens, and, in consequence, the ground at his feet is seen only indistinctly. Those who use these lenses must accustom themselves to bending the head and looking through the top portion of the lens when mounting a 'bus, or going up or downstairs.

When these are worn, it is necessary that the frames fit very accurately. Some people declare that they cannot become accustomed to bi-focals, no matter how well they are adjusted. The segment of a bi-focal should always be decentred inwards a trifle; whereas the optical centre of the distance portion should be in the geometrical centre of the lens. Although bi-focals are very convenient, and are worn by many with comfort, you should always be careful to explain the peculiarities

connected with them (as previously mentioned) to intending wearers, and if the patient cannot easily get accustomed to them, it is better to give two pairs of spectacles.

Tinted or coloured glasses only increase the tendency to Photophobia, instead of alleviating it. Unfortunately, many people are given coloured lenses to wear, who complain of Photophobia, which could be effectually remedied by prescribing the necessary ametropic correction. There are, of course, cases where coloured lenses are necessary, such as after Cataract extraction, or inflammation, or in Cycloplegia. But they should not be prescribed indiscriminately, when the patient complains of not being able to stand a strong light on the eyes; the cause of this condition should be ascertained and removed, when the Photophobia will also disappear. Tinted glasses are necessary for occasional use, when at the seaside, or sometimes when the snow is on the ground, because the white surface of the ground reflects the light upward, and the eye, being unaccustomed to the light falling upon it from this direction, becomes weak and irritable. Under such conditions, prescribe coloured glasses for occasional wear.

Glasses of a globular shape, called "coquilles," are often worn for protection when cycling or driving; but unless these are well ground, there is apt to be a cylindrical element about them, which is detrimental to the sight. Protecting glasses are also necessary for stone-breakers and others whose employment necessitates their eyes being exposed to injury.

In the early part of this chapter we were informed that if a frame fits badly, it gives to the lens a prismatic effect, and is injurious to the eyes. When prisms are necessary for occasional use (which cases are rare), instead of using prisms, which are both cumbersome and unsightly, the required prismatic effect is obtained by intentionally decentring the lens necessary to correct the Ametropia in the desired direction. Such lenses are called "Prismospheres," and were fully described on page 59.

In order to obtain a prismatic effect, *base out*, with a convex lens, it is necessary to decentre the lens *outward;* and conversely, with a concave lens, to obtain a prismatic effect, *base out*, the lens must be decentred *inwards*. The reason of this will be understood if it is remembered that spherical lenses are composed of prisms (see p. 26).

So as to obtain a prismatic effect of 1°, a 1D. lens must be decentred 8·7 millimetres. In order to ascertain the amount of decentration required to obtain a certain prismatic effect in a given lens, it is necessary to multiply 8·7 by the prism one wishes to use, and divide the result by the dioptre-number of the lens to be decentred.

Example. — The decentration necessary to obtain a prismatic effect of 2°, base out, in a + 4D. lens, would be a little over four and a quarter millimetres outwards, as follows:

$$\frac{8{\cdot}7 \times 2}{4} = \frac{8{\cdot}7}{2} = 4{\cdot}35 \text{ millimetres.}$$

Now it would be interesting to reverse the above process; that is, to find the prismatic effect produced by a certain decentration of the optical centre of a lens. In order to do this, we must multiply the amount of decentration by the power of the lens, and divide the result by 8·7 millimetres. Let us prove this by experimenting with the example just given.

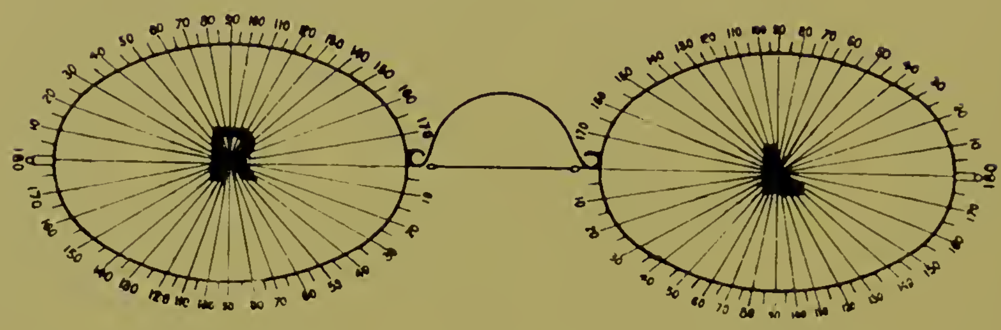
A 4D. lens decentred 4·35 millimetres outward. What is the prismatic effect thus produced?

$$\frac{4{\cdot}35 \times 4}{8{\cdot}7} = \frac{17{\cdot}40}{8{\cdot}7} = 2^\circ \text{ prism, base out.}$$

From the above repetition (rules for decentration having been previously given in Chapter III.), it will be clear what effect is produced by a carelessly chosen frame. It would be well to explain this to any patient who has no regard for a perfect fitting frame.

Optician's Prescription Book.

THE PRESCRIPTION.



LENSES. Reading Distance.

R			L		
SPH.	CYL.	PRS.	SPH.	CYL.	PRS.

FRAME MEASUREMENTS.

1 *Facial Breadth* ______

2 *Pupillary Distance* ______

3 *Height of Bridge from centre* ______

4 *Position of Bridge* { ***A*** *Projecting from Wearer's Face* ______
{ ***B*** *Receding towards Wearer's Face* ______

5 *Sides* { *Single* ______
{ *Curl*

Name ______

Date ______ *Signature* ______

The prescription blank shown on page 250, is a useful form, and is one generally used in ordering the necessary lenses and frames. The powers of the lens combinations are filled in the spaces indicated; a line run through the diagram at the top showing the direction of the cylindrical axis. The various frame measurements are described in the spaces provided beneath, unless a 'prescription set,' such as has been described, is used—when the frame number only is given; as this indicates all the particulars necessary.

A few more words in conclusion.

When ordering spectacle frames, the measurements to be particular about were those shown in Fig. CIII., and when ordering eyeglasses, the particular pattern chosen need only be quoted—also the distance between the faces of the guards or placquets, measuring from the centre of the guard when they are movable; or when fixed, the distance between the faces at the top and bottom should be given. (If the eyeglasses are 'astigs,' they should be at rest when this measurement is taken). It is not necessary to give the P.D. or facial measurement of the patient, as this kind of frame adapts itself to the wearer's face.

Do not trust to any measuring rule to ascertain the dimensions of your patient's face, but fit on a frame until you obtain one of the required size—and then, if necessary to order another frame like this, measure up the original frame, which fits your patient, or if using a measuring set, as mentioned just now, quote the frame number.

Lenses are made in several sizes, the average calibre being "No. 1 eye," as it is called. This certainly suits a great number of faces, but there are people who require a smaller size—ladies for instance. Others, in order to obtain a well proportioned frame, would require to have a larger eye than the No. 1; and "0 eye," which is the next size larger, is usually found to fill the requirements of these. (By referring to illustration CX., you will see the several sizes of

"eyes.") The smallest size necessary is "No. 3 eye"; the lenses range from this, gradually larger, to "No. 00 eye." A

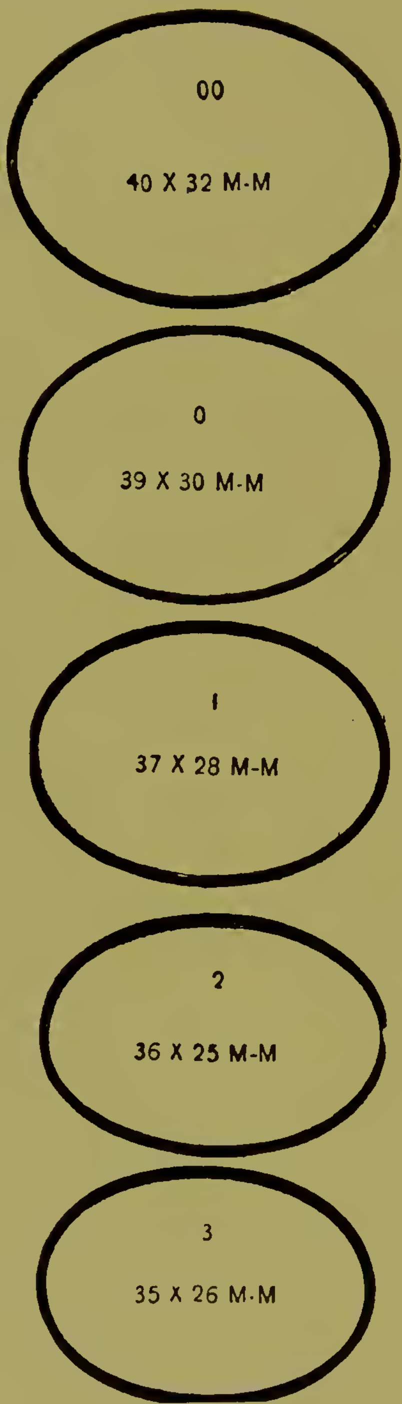


FIG. CX.

larger glass than "00" is seldom required. Occasionally a round eye is advisable for children, so as to prevent them from

looking through the edges of the lens. Of course, there are frames made to correspond to these various sized "eyes."

Before closing this chapter and leaving the subject of lenses, we will just mention one more form, which the reader may hear of some time or other—viz., the Orthoscopic.

An Orthoscopic lens is composed of a prism on which is ground a convex surface. The object of such a combination obviously is to furnish assistance to the Internal Recti at the same time as to the Ciliary muscles in reading. Theoretically these lenses are all right; but practically they are a failure, owing to the very strong prism it would be necessary to use in combination with convex spherical lenses of 3D. and over; and in the weaker numbers, the difficulty and expense of making them would prohibit their use.

CHAPTER XV.

SPHERICAL ABERRATION.

We have hitherto been supposing that all rays of light, on passing through a convex lens, are brought to a single point at the principal focus of the lens. This is what *ought* to occur, certainly, but because this is not exactly what does take place, we will devote this chapter to dealing with Spherical Aberration.

What this really is, may easily be seen from the following diagram:—

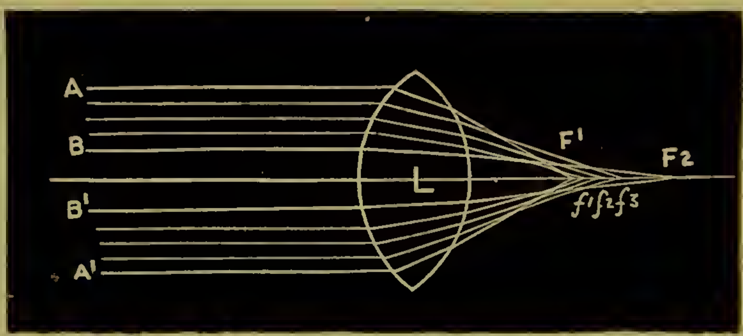


FIG. CXI.

The circumferential rays AA^1, falling on the lens L, at a greater obliquity than the rays BB^1, are brought to a focus at F^1; whilst the rays BB^1, which fall upon the lens near the centre, are focussed at about F^2. Thus, spherical aberration exists when rays of light passing through a lens are focussed at several distances from it. Rays striking the surface of the lens between AA^1 and BB^1, meet at intermediate distances along the

principal axis; say at f^1, f^2, f^3. The effect produced by the unequal refraction is a distorted and blurred image.

Thus it is seen that the further rays fall on a lens from its optical centre, the greater is the refraction that the rays undergo. This peculiarity is called "Spherical Aberration."

This aberration is not sufficiently marked, in the lenses we use in visual optics to correct refractive errors, to cause any trouble; but in optical instruments it must be counteracted, as otherwise it would seriously interfere with the distinct definition of an object, by preventing a sharp outline.

Lenses may be so constructed as to unite all rays passing through them at one point, called the principal focus, and such a lens is termed "aplanatic."

Since it is the peripheral rays which cause this aberration, it may be obviated in optical instruments by means of diaphragms, which exclude these marginal rays.

In the human eye, the Iris acts as a diaphragm; and it is on account of this excluding all but the central rays that the spherical aberration is almost corrected in the eye—at all events, sufficiently to prevent any indistinctness of the periphery of the retinal image which would otherwise occur. The Crystalline Lens, being so made that it diminishes in refractive power as it approaches the margins, also has a great deal to do with correcting the spherical aberration of the eye.

CHROMATIC ABERRATION.

White light is made up of seven different colours—viz., red, orange, yellow, green, blue, indigo, and violet.

It is due to their unequal refrangibility that Chromatic Aberration is produced. The red rays are the least refracted of them all, and the violet rays the most. The intermediate colours are refracted in degrees varying between these two extremes; becoming gradually more refrangible as they approach the violet rays.

We have just seen that Spherical Aberration only occurs when rays of light fall on a lens at different distances from the optical centre, whereas Chromatic Aberration consists of a splitting up or dispersion of the several parts of one ray of light.

The spectrum consists of the seven constituents of white light as enumerated, and since prisms increase the dispersion of these colours, they can be easily seen by the following experiment.

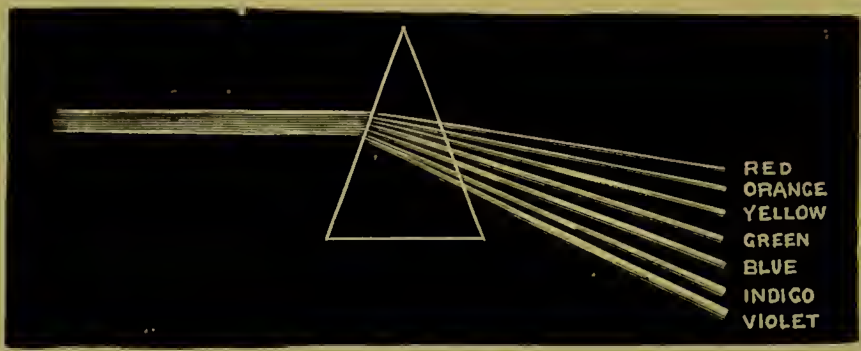


FIG. CXII.

Make a small aperture in the shutter of the window of a darkened room, and allow the ray of light entering the room to pass through a prism, when the spectrum can be received upon a screen, and the colours may be distinctly depicted. The red end of the spectrum will be towards the apex of the prism, and the violet will be seen in the direction of the base (see Fig. CXII.).

The Chromatic Aberration is not perfectly corrected in the refractive media of the eye, as is proved by the presence of coloured edges of a luminous object, if seen when one half of the pupil is covered with a card. But the different indices of refraction and dispersion of the humours of the eye correct it sufficiently to prevent any interference, under ordinary circumstances; also the Iris counteracts Chromatic as well as Spherical Aberration.

This dispersion of the colours, although too inconsiderable to require correcting in the ordinary spectacle lenses, would cause very serious interference if left uncorrected in the finer optical instruments, such as the telescope or microscope; so that in these instruments achromatic lenses are used, which are constructed by combining crown and flint glass—the latter having almost twice the dispersive quality of the former—in such proportion as to entirely neutralize the Chromatic Aberration.

The chromatism of the eye is proven by the appearance of a candle flame viewed through a piece of cobalt-blue glass.

Such a lens excludes all rays of the spectrum, except the red and the violet. The flame thus seen will therefore appear to have either a red centre and a bluish halo, or a blue centre surrounded by a red margin, according to the condition of the refraction of the eye being tested.

It is upon the principle of the suppression of all colours of the spectrum, save the red and violet, by a lens of cobalt-blue, intensifying the latter, that we have an exceedingly pretty method of ascertaining the refractive condition of the eye.

In order to understand this method of testing, it should be remembered that the red are the least and the violet the most refrangible rays of the spectrum.

In this test, the object used is the naked flame of a lamp or candle, placed, if convenient, at six metres' distance, and viewed through the cobalt-blue glass (called the chromatic lens), when the red rays, being the least refracted, will not meet so soon as the violet rays.

If the refraction of the eye is normal, the focus of the red rays will be as far beyond the Retina as the violet ones are in front of it. Consequently, in Emmetropia the two colours intermix, and the flame of the candle will appear a reddish violet, but with a slightly blue border.

If the Retina is situated closer to the Crystalline Lens than it should be, it will approach the focus of the blue rays,

the red ones focussing behind it, which causes the flame to appear with a blue centre and a red margin. This is how the candle flame is seen in Hypermetropia.

If, on the other hand, the eyeball is prolonged unnaturally from before backwards, the Retina approaches the focus of the red rays; and therefore in Myopia the image of the flame will appear with a red centre, surrounded by a blue halo.

To find the amount of the defect in Hypermetropia, we place convex lenses before the chromatic lens, until we obtain the strongest one that dispels the red halo and changes the flame into one colour, a violet-red.

In Myopia, we prescribe the weakest concave lens which converts the flame into the one colour.

In Astigmatism, it is too confusing for the patient to accurately explain the direction in which he sees the two colours; so that for this defect the Chromatic Test is practically useless—so we will not waste time by describing the various appearances of the flame in this condition of the eyesight.

Of course, in Hypermetropia and Myopia, the Chromatic Test should only be used corroboratively.

CHAPTER XVI.

SKIASCOPY, OR RETINOSCOPY.

It is not intended in this chapter to enter exhaustively into the subject of the "Shadow Test," as retinoscopy is popularly called; but merely to consider such details as are necessary for a thorough comprehension of this method of testing, so that the reader, after following these few pages carefully, may be in a position to understand the different appearances of the pupil during the procedure of testing with the mirror.

The theory of retinoscopy is extremely simple, and quickly committed to memory, but like all other manipulations, requires a certain amount of practice before any one is in a position to fully appreciate what is observed in the pupil under refraction.

My advice to a beginner in this connection is, to use the retinoscope in every case that may come under his notice, after having first ascertained with the trial lenses the state of affairs present, and also the correcting glasses. In this way, if he uses the retinoscope first without the correcting lenses before the eye, and afterwards, with them placed in position, he will be able to study the different appearances of the eye *without* the necessary correction, and *with* it—which will represent first, an ametropic, and next an emmetropic eye. In this way he can familiarise himself with the several refractive conditions he may meet with; and additionally it forms a means of confirming one's test with the trial case.

It is well to state here that no correction found with the retinoscope should be prescribed for a patient, under any circumstances, until first verified by the subjective test, unless the patient is incapable of being examined subjectively.

Subjective tests are those in which the examiner has to rely, to a certain extent, upon his patient's intelligence in replying to questions put to him.

Objective examinations are conducted without any assistance whatever from the patient; and are therefore to be preferred in some cases. Retinoscopy is certainly one of the most useful methods of ascertaining the general refractive condition of a patient. It is especially useful in cases of young children or illiterates; or, in fact, with anyone upon whom you could not depend for a reliable answer.

In retinoscopy, you ascertain the refractive condition of the patient by reflecting into the eye under examination, a light from a plane or concave mirror; and note the direction of the movement of this illumination in the pupil, by rotating the mirror.

The advantages are that:—

It forms a quick method of examining the eyes; and it is performed without having to rely upon the help of your patient; and lastly, the outfit necessary is most inexpensive.

It is not absolutely necessary to use atropine; although in order to obtain the most satisfactory results, it is better for the Ciliary muscle to be under the control of a reliable Cycloplegic.

The requisite outfit consists of the following:—

The *retinoscope*, or mirror (Fig. CXIII.), is of two forms; a large one, four centimetres in diameter; and the other, smaller, being only about two centimetres in diameter, secured to a disc of black metal.

The sight-hole or aperture of the mirror may either be cut through the glass or formed by the quicksilver being removed. This latter method, of course, leaves the glass over the sight-hole, making an additional reflecting surface at this

spot, which is an advantage, as it diminishes the dark central shadow that is too conspicuous when the aperture is cut through the glass. The small mirror with the black background is the one preferred by the author, as it reduces the amount of reflected light, which is consequently not so dazzling to the patient's eye. Of course, the larger the mirror, the

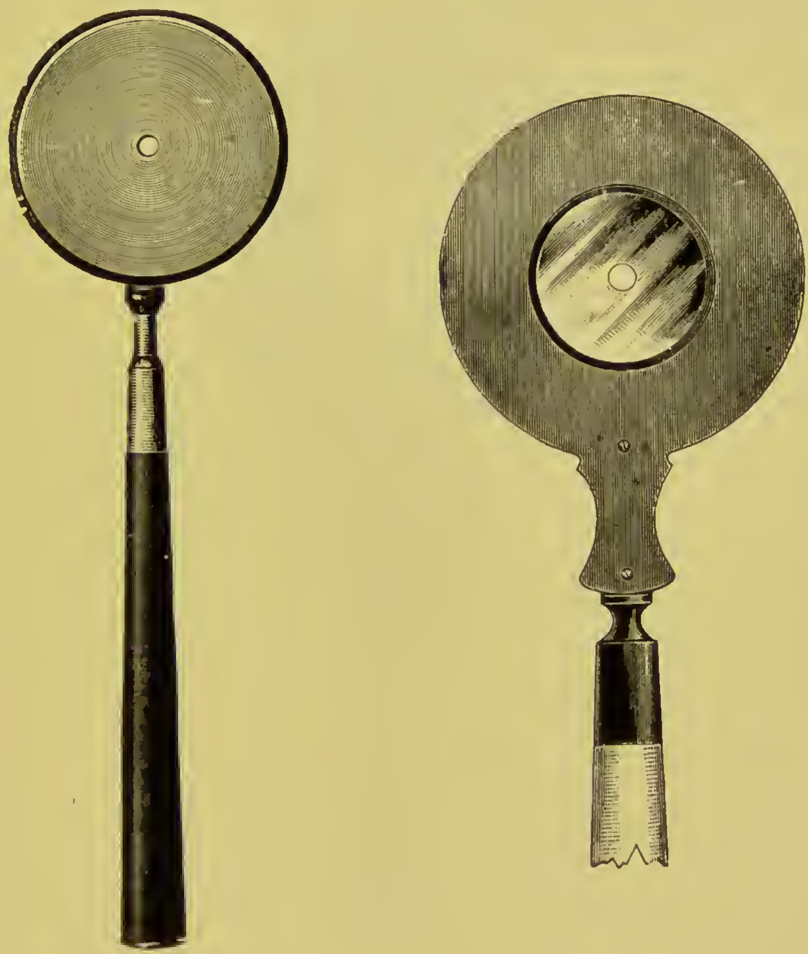


FIG. CXIII.

easier it is to work with; and beginners will find that with it the illumination is not so easily lost from the patient's face; also it does not require so steady a hand to manipulate it, as the smaller one.

A new retinoscope has lately been introduced by the Anglo-American Optical Company, of Hatton Garden. It is fitted with an "Iris" diaphragm in front of a plane mirror, which can be adjusted to any size from five to thirty

millimetres diameter, simply by turning a graduated screw, on which is marked the diameter of the mirror in use (see Fig. CXIV.).

With this instrument the tyro may become proficient in the manipulation of both the large and small mirrors; because, as he becomes more expert in handling the instrument, he can

Fig. CXIV.

reduce the diameter of his reflecting surface. There is, as has just been explained, less reflected light when using the small mirror; consequently it is less dazzling to the patient, and therefore holds an advantage over the large retinoscopic mirror; but, of course, more practice is required to become proficient in using it.

The *Light*.—This may be either electric or gas with an incandescent mantle; or any other illumination, provided only

that it is steady, clear, and white. When using the electric light, it is advisable to have a *ground*-glass "bulb" or globe.

If the illuminant is a gas or other flame, it should be covered with an asbestos chimney; so that all the flame is hidden except the portion which is in use, at the opening in the side of the chimney. The best kind of chimney is the one having an "Iris" diaphragm at the opening; so that the amount of light may be regulated (see Fig. CXV.). These three items constitute the necessary outfit.

The room in which the examination is conducted must be darkened as much as possible; the darker the better, for the

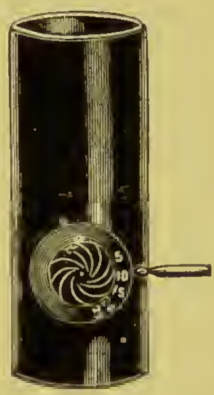


FIG. CXV.

purpose of the shadow test. The only source of light is the one we are using. It is not necessary to have a room specially fitted—an ordinary one will suffice, with the shutters drawn; but should this be inconvenient, a portion of the testing-room could be screened off by means of black curtains, so as to obscure the light.

The position of the source of illumination is optional, to a certain extent; but it should be in such a position as to leave the eye under observation in shadow. The light is usually placed either behind and above, or to one side of the patient's head; or, if more convenient, it may be placed next to the examiner, in such a manner as to throw the light immediately on to the retinoscopic mirror. In this way you obtain a better

illumination (see Figs. CXVI. and CXVII.). It should not, in any case, be placed closer to the mirror than about twelve centimetres (five inches).

The mirrors in use are either plane or concave—the former is the simpler and easier method of working; so all future descriptions of retinoscopy will refer to the plane mirror. If the concave mirror should be preferred, it is generally one having a focal length of twenty centimetres; and the patient and observer must be separated by a distance of one and a quarter metres (one metre twenty-five centimetres).

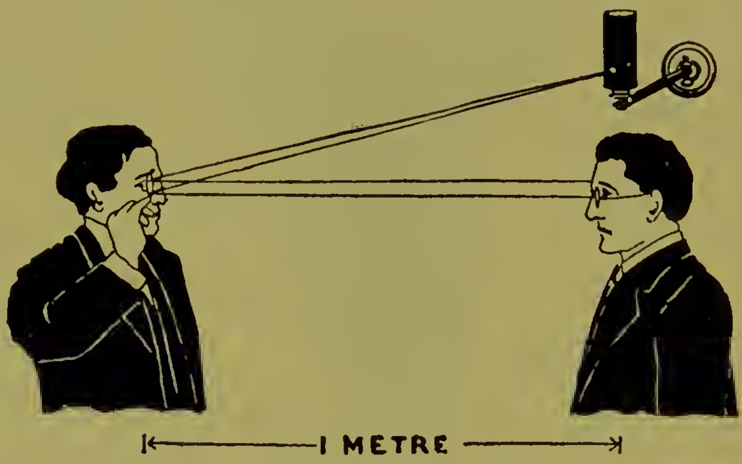


Fig. CXVI.

The indications afforded by the concave mirror are the reverse to those obtained with the plane one, now to be described.

Before contemplating the actual routine of testing, it is necessary for the beginner to familiarise himself with the following few rules, and to memorise them :—

1. The patient should be seated facing the observer, at a distance of one metre (or forty inches); and he must be told to fix some distant object at the farthest end of the room, which, being darkened, will prevent the patient from seeing very much. But the object of instructing him to look at a distance is, to relax the accommodation as much as possible;

since we are not using cycloplegics. He must not look at the mirror; as to do so, necessitates the accommodation being brought into play—and also the reflected light from the mirror will cause the pupil to contract, and in this way render the testing more difficult; but the patient should look over and beyond the observer's right shoulder when the right eye is under examination, and over the left shoulder when the left eye is being tested.

2. The mirror should be held in the right hand, before the observer's right eye, so that the sight-hole is directly before the pupil. The retinoscope may be rested against the

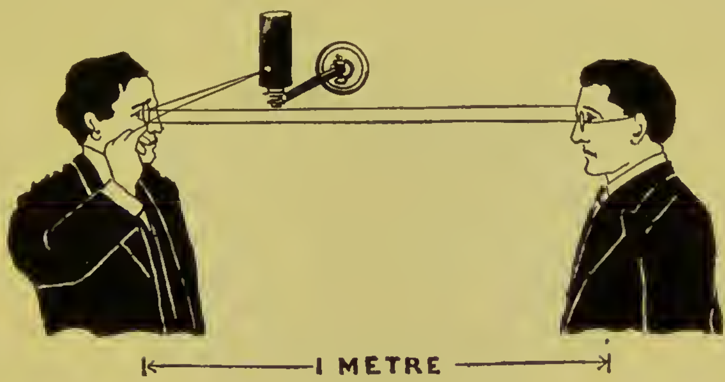


Fig. CXVII.

side of the nose, and the handle against the cheek, so as to ensure its being quite steady.

3. The mirror should be moved very little; otherwise the illumination will be reflected off the patient's eye—but it may be moved quickly or slowly, whichever is most convenient at the moment. Generally the mirror is tilted quickly, at the commencement of the test; but when approaching the correction the movement should be slower. Keeping the light on the patient's face is one of the greatest difficulties experienced by the novice; so that it is advisable to have some practice with an artificial Skiascopic Eye (see pages 279 and 280) before attempting it with the human one.

4. On the patient's face the illumination will always be in the direction of the tilting of the mirror; but in the pupil itself this is not necessarily the case.

5. If the movement of the shadow in the pupil is with that of the mirror, it indicates either Emmetropia, Hypermetropia, or Myopia of less than 1D.

6. If the shadow moves in the opposite direction to that in which the mirror is tilted, it shows Myopia of over 1D.

7. If the movement of the shadow is equal in all directions, there is no Astigmatism present; or if the edge of the non-illuminated part of the pupil is curved or spherical, it also indicates a spherical correction (Fig. CXVIII.).

Fig. CXVIII.

8. The observer in retinoscopy is testing the meridian in which he tilts the mirror.

9. If the rate or direction of the movement of the shadow differs in two meridians; or

10. If the retinal illumination appears to be a band stretching across the pupil, it signifies Astigmatism. And also when the edges of the shadow are straight, it indicates a cylindrical correction (Fig. CXIX.).

11. The principle of retinoscopy is to reverse the movement of the shadow, and this is done by placing before the eye convex or concave lenses, as the case may be, until one is

found which accomplishes this, then, the lens *just weaker* is the correction.

12. If a bright ring of light is noticed at the margin of the pupil, it should be disregarded; as it is due to the strong peripheral refraction (or spherical aberration of the eye; refer to page 254), and cannot be obviated.

13. A most important point in retinoscopy is to remember to add −1D. to the correcting glass found in the dark room, when trying patient's visual acuity at the distance test charts, after obtaining the skiascopic correction.

14. The rate and extent of movement of the shadow is invariably in inverse proportion to the degree of the Ametropia.

Fig. CXIX.

The duller the illumination, and the less the movement of the shadow, the greater is the amount of the Ametropia.

15. The central shadow referred to a little while back, as the result of the central aperture of the mirror, will cause considerable annoyance to the beginner. So he had better become acquainted with it before undertaking to test a patient, by reflecting a light with the mirror on to a screen; when he will at once see its position and origin.

With a knowledge of the foregoing rules, the reader will be able to appreciate the following description of the procedure of the "Shadow Test."

After carefully adjusting the trial frame on the patient's face, so that he looks through the centres of the lenses—which, when used, should be placed perfectly upright before the eye—the observer, seated facing the patient, at a distance of one metre, reflects the light from the source of illumination (which is placed either near the patient's head, or close to the mirror; refer to Figs. CXVI. and CXVII.), into the observed pupil—the room, of course, being darkened, and the patient directed to look into vacancy, or as far away as circumstances will permit.

On looking through the sight-hole of the mirror at the patient's pupil, it will appear red or pink. The less the degree of defect present, the brighter will the retinal illumination appear.

The refractionist now gently rotates the mirror on its vertical axis, and watches the movement the shadow makes across the pupillary area. The shadow is the non-illuminated portion of the pupil. If the shadow moves quickly in the same direction as the mirror, the eye being tested is either emmetropic, hypermetropic, or myopic of under 1D.

The observer now places in the trial frame a + 1D. lens; and if this reverses the movement slightly, or renders it so rapid that its direction cannot be ascertained, the patient is emmetropic.

The reason is, that − 1D. has always to be added to the correcting lens found in the dark room, when testing at one metre, which entirely neutralizes the + 1D.

If the lens slightly weaker than that which just reversed the shadow was + 3·50D., it would indicate Hypermetropia of + 2·50D. But on the other hand, should the lens that stays all movement be *less* than + 1D., then the patient is myopic of under 1D. Say, for instance, the lens is + 0·50D., the condition indicated would be Myopia of 0·50D.; thus + 0·50, added to − 1D., equals − 0·50D.

If the movement of the non-illuminated portion of the pupil be against that of the retinoscope (mirror), then the patient is myopic of more than 1D., and the observer would place in the trial frame concave lenses, until he obtained the one that just made the shadow move *with* the mirror. If this lens was – 2·50, the dark room correction would be – 2·25, if – 2D. was found to make the shadow move still against the mirror. And the infinity correction would equal – 2·25, added to the customary – 1D., which is – 3·25D.

If the shadow moved quicker, or in different directions, in the several meridians, Astigmatism is present, and the plan is to locate the two principal meridians, and then to correct the movement of the shadow in the meridian of least defect first (*i.e.*, where the movement of the shadow is quickest) with spherical lenses, and then add to that lens to correct the other meridian. Or, if preferred, the meridian of least Ametropia may be corrected with spheres, and the other direction with cylinders. When the meridian of least defect is corrected with spherical lenses, it will be seen that there is now a band of light across the pupil. The meridian just corrected corresponds to the direction of this band; and, consequently, the axis of our cylindrical lens would be placed in this meridian. Now, in order to correct the most defective meridian, cylinders are added to the sphere already before the eye, and which corrects the one principal meridian, until the movement of the shadow is reversed in the worst direction also; the axis, of course, being placed in the position corresponding to the band of light seen across the pupil.

The observer can always tell if the patient is looking at a distance during the testing or not; because as soon as the patient attempts to look at the mirror, the pupil immediately becomes smaller, and the fundus reflex (*i.e.*, the reflection of the fundus or back of the eye, which is seen in retinoscopy) becomes perceptibly fainter.

In the Shadow Test, generally both eyes are left uncovered all the time; but in cases of Strabismus it is well to place the blank disc before the eye not being tested. In this way, when testing the deviating eye, it is induced to resume its natural position, if the patient is told to fix some distant object; whilst the perfect eye, which is covered over, does the squinting.

With the object of making the procedure just explained thoroughly comprehensive, the following examples of the different cases are given; and if they are carefully followed, the reader will see where each of the rules previously given in this chapter is brought into use. It must be remembered that by retinoscopy we are able to estimate only the necessary *distance* correction, and do not ascertain the reading glasses; but this test must be supplemented by the usual reading tests, in the same way as if the trial case had been the means used for finding out the distance glass.

The observer must wear his own correction, if any; but his accommodation does not interfere with results, as it does in ophthalmoscopy.

Example I.—Emmetropia.

Retinal illumination very bright; and shadow moves quickly, *with* the mirror. On placing + 1D. before the eye, the movement is very rapidly with that of the mirror; and + 1·25D. just reverses this direction—makes it go *against* the movement of the mirror; therefore + 1D. is the correcting lens, according to the retinoscopic test.

For infinity no glass is required, because we add − 1D. to it, as the testing is conducted at one metre's, or forty inches', distance.

Rule.—It is essential that when changing from the dark room to the infinity or six-metre correction, the refractionist should make an allowance for the distance from the patient's

eye to the observer; that is, if working at two metres, or eighty inches, allow 0·50D., or if at a quarter of a metre (ten inches), allow 4D., and so on.

Example II.—Hypermetropia.

The retinal illumination in this case is rather dull at first sight; but on telling patient to look at a distance, it becomes somewhat brighter, and the pupil larger, which shows that now the accommodation is more relaxed than formerly, when the patient must have been looking at some close object, probably the mirror.

On trying + 1·50, the fundus reflex becomes much more distinct, and the movement of the shadow, though still with the mirror, is much quicker than before. It is found that + 3·50 is the strongest lens which gives a movement of the shadow, still with the mirror; + 4 making it move against it. The measure of the defect, then, is 3·75; that is, the glass between that which reversed the movement and the strongest lens with which it remained with the mirror. The infinity correction in this case is + 2·75, as in these examples we are working at one metre's distance.

Example III.—Myopia.

Movement of the shadow is quick, and against the mirror, showing a Myopia of something over 1D. On trying − 1D. before the eye, the movement went in the *same* direction as the mirror; which showed that the lens was too strong. On reducing it to − 0·75, there was, apparently, *no* movement at all of the shadow, which proved this to be the correct lens. The twenty feet, or infinity, correction is, therefore, − 1·75, after adding the − 1D.

Example IV.—Astigmatism, Simple Hypermetropic.

The fundus reflex seems to be fairly bright; but the movement of the shadow, although rapid, seems to be unequal, and with the mirror. The movement is noticed to be more rapid in the vertical; so this is the meridian of least Ametropia, and therefore is the direction to be corrected first. On placing a + 0·50 sphere in the trial frame, before the eye in question, the movement is not entirely dispersed, but still remains with the mirror. However, a + 1D. is found to correct it entirely in the vertical meridian; but in the horizontal it is still somewhat with the mirror, and after making a mental note of the lens which corrects the vertical direction, this lens is increased in power. The one which reverses the horizontal movement is + 1·75, so it requires + 1·50 to remove the shadow. The above correction is graphically:—

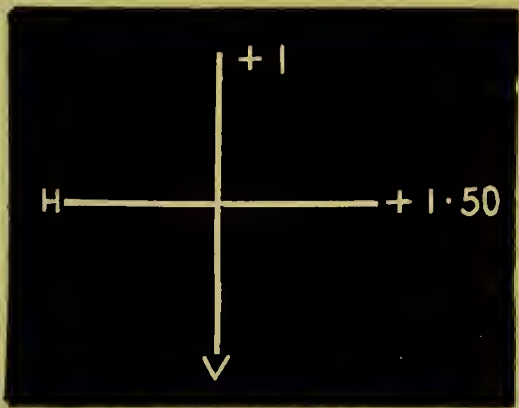


Fig. CXX.

which represents the following error, on adding − 1D. to the above:—

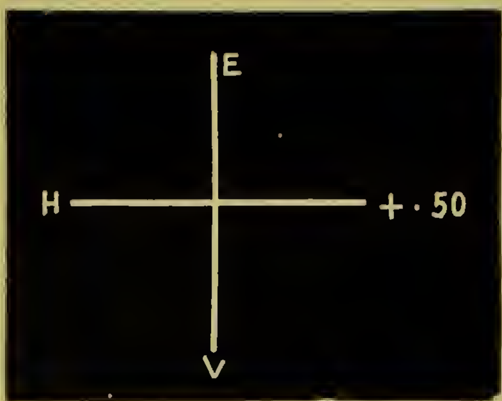


Fig. CXXI.

So the lenses to be prescribed, provided it is confirmed with the trial case would read :

+ 0·5 cyl. ax. V.

Example V.—Astigmatism, Compound Hypermetropic.

In this case the retinal illumination is very dull, and the shadow moves slowly with the mirror. This at once looks like a bad case of Hypermetropia, so we place + 4D. before the eye,

Fig. CXXII.

when the reflex immediately becomes brighter, and the movement quicker. On increasing this to + 5D., the retinal illumination appears as in Fig. CXXII. In the vertical there is no shadow at all on rotating the mirror; but in the horizontal the movement is still with it.

The + 5D. evidently corrects one direction, but not the other; so it is changed to + 6D., and then to + 7, and this renders the movement in the horizontal slightly against that of the mirror. So we reduce it to 6·50, and then it is seen that with this the shadow again goes in the direction in which the mirror is tilted. This tells us that + 6·75 is wanted to correct the horizontal.

This condition is drawn thus:—

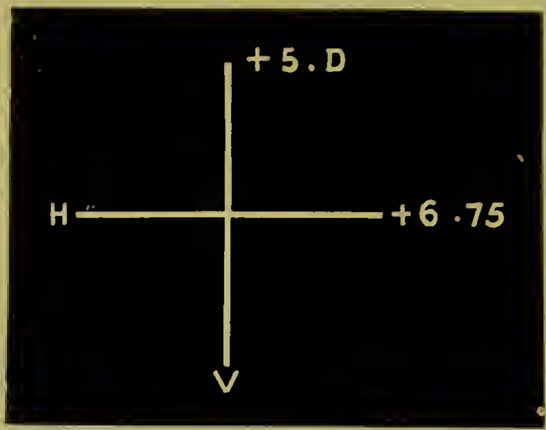


Fig. CXXIII.

and the infinity correction, after the necessary deduction, is:—

+ 4 sph. ⊂ + 1·75 cyl. ax. V.

The above case could have been corrected by cylinders, placing the axis in the vertical, and increasing their power until the shadow is dispelled in the horizontal; instead of continuing with spheres after correcting the meridian of least defect. But it is not so simple to do as the latter; therefore it is better to test outright with spherical lenses, and transpose the combination into a sphero-cylinder form afterwards, when testing the acuteness of vision with the distance test types.

Example VI.—Astigmatism, Compound Myopic.

With the retinoscope, the movement of the shadow is against that of the mirror, but appears to be quicker in the horizontal than in the vertical direction. On placing lenses before the eye in the trial frame, it is found that −3D. stops the movement in the horizontal; but −5D. is required before the vertical meridian is corrected.

The retinoscopic result reads :—

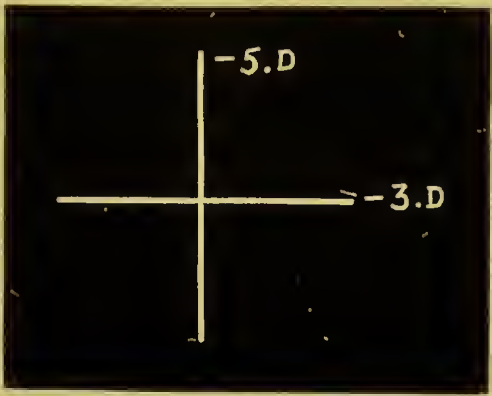


Fig. CXXIV.

which gives the infinity correction as :—

$$-\ 4 \text{ sph.} \bigcirc -\ 2 \text{ cyl. ax. } 180^\circ.$$

Example VII.—Mixed Astigmatism.

On placing patient in the dark room, by retinoscopy we find that the movement is *with* the mirror in one meridian, and in the other it appears to be *against* it. On trying a +2D. before the eye, the movement is stopped entirely in one direction; and the appearance of the retinal illumination presented to the observer is a distinct band of light running across the pupil obliquely, as near as can be judged, in 135° meridian. This indicates the position of the meridian just corrected by the +2D. sphere; and also the direction in which the axis of the cylinder will be placed eventually. We now rotate the mirror in the direction corresponding to 45° meridian and endeavour to remove the shadow, or reverse it in this direction. As it is against the mirror, we try a −1D., which is found to reverse the movement slightly; showing a −0·75D. to be the lens required to correct this meridian.

The retinoscopic result reads :—

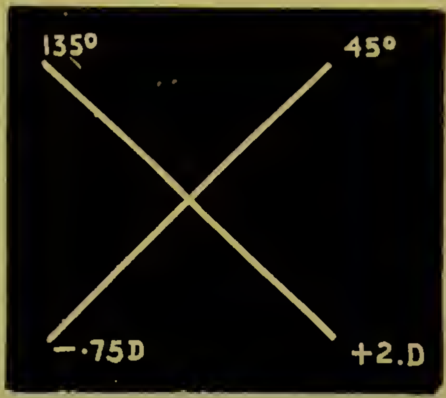


FIG. CXXV.

and on adding -1D. to this, it becomes :—

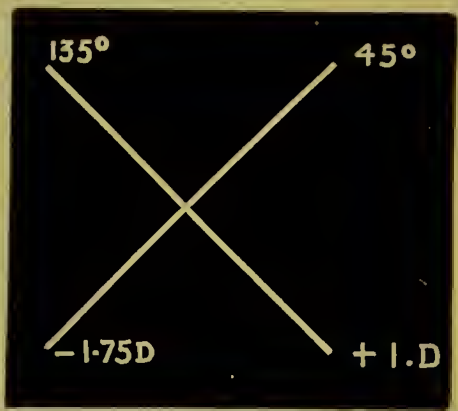


FIG. CXXVI.

which is transposed into this prescription :—

$$+1 \text{ sph.} \bigcirc - 2{\cdot}75 \text{ cyl. ax. } 135^\circ.$$

The patient should now be seated at the requisite distance from the distance test chart, and his visual acuity ascertained ; and this correction confirmed with the trial lenses.

EXAMPLE VIII.—MIXED ASTIGMATISM.

This example is merely to show another result which also denotes Mixed Astigmatism ; although at first sight it

appears to be only compound. By retinoscopy we find this result :—

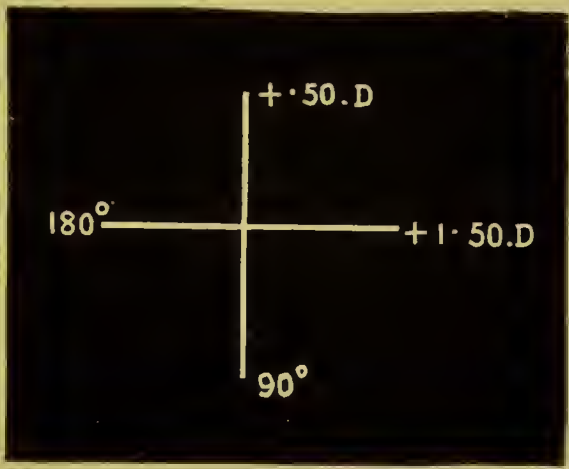


FIG. CXXVII.

To the tyro this appears to be Compound Hypermetropic Astigmatism; but when the customary – 1D. is added, it becomes a case of Mixed Astigmatism :—

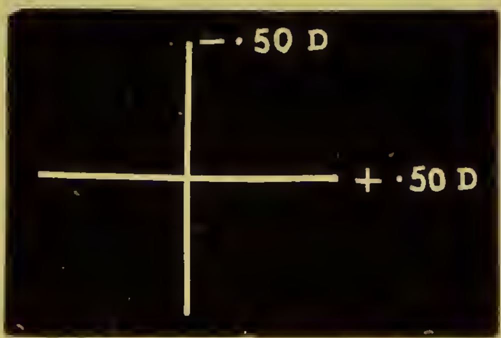


FIG. CXXVIII.

the cylindrical combination of which is :—

$$-\ 0{\cdot}50 \text{ sph.} \bigcirc + 1 \text{ cyl. ax. } 90°.$$

RETROSPECT.

Points to be observed :—

1. Examiner should always be seated at the same distance from the patient—one metre if the mirror used is plane, or one and a quarter metres if concave.

2. It is of little consequence which mirror is used; it is a matter of choice; but the indications afforded by the two mirrors are opposite.

3. Ascertain first, whether the movement is equal in all meridians. If it is not, locate the two principal meridians, as there is Astigmatism present.

4. Also note whether the shadow is straight-sided or curved. If the latter, only spherical lenses will be required to correct the Ametropia present.

5. Notice if the movement is quick or slow, and also whether the reflex is bright or dull; as this indicates approximately the degree of the defect.

6. See the direction of the movement of the shadow, so as to ascertain the kind of error present.

7. In Astigmatism, the direction of the band of light which is seen *after* one meridian is corrected with a sphere indicates the direction of the cylinder in the final correction.

8. When Astigmatism is present, correct each meridian *separately* with *spherical* lenses; and afterwards transpose the correction.

9. The object in testing is, to find the point of reversal; and the correction is the lens just weaker than the one which reverses the movement of the shadow.

10. When changing from the dark room to the infinity correction, never forget to allow for the distance at which you were testing in the dark room. Always add −1D., if this is one metre from the patient.

11. The rate and amount of fundus reflex, and the brightness of the edge of the retinal illumination, are in inverse proportion to the degree of refractive error.

12. The retinoscopic result must *not* be considered as the *final* correction.

It should be observed that in retinoscopy it is not necessary to begin trying the weakest convex or concave lens, as the case may demand; but from the appearance of the retinal

illumination the observer can approximate the power of the lens necessary. Of course, the more practice the refractionist has, the nearer he arrives at the required glass.

As was explained at the opening of the chapter, it is not intended to go deeply into this subject; but the endeavour of the writer has been more to explain the method of using the retinoscope, by giving, in as simple a manner as possible, the

Fig. CXXIX.

several essential rules upon the subject, so that the refractionist might include this valuable method of testing in his daily practice.

Before bringing this chapter to a conclusion, a brief description of the Schematic or Skiascopic Eye, for use in practising skiascopy, would not be out of place.

The eye illustrated above is made of two brass or cardboard tubes, the front one being somewhat the larger of the

two, so that they fit easily one into the other. The smaller tube is closed at the posterior end, and on the inner surface is a representation of the normal Retina, from which is obtained the necessary reflex. The large tube is also closed at one end, in front; leaving a small aperture, which is occupied by a strong convex lens, representing the Crystalline Lens. Attached to the outer end of the larger tube are two cells, made to hold the trial lenses; and the different meridians of the eye are also marked on it. On the side of the small tube is a scale, which indicates Emmetropia, or the amount of Hypermetropia or Myopia, according as the tubes are pushed in or are drawn apart.

In order to practise testing an astigmatic eye, it is only necessary to place in the grooves provided a cylindrical lens in any desired axis. In this way the beginner in retinoscopy can become acquainted with the characteristic conditions of this defect.

CHAPTER XVII.

OPHTHALMOMETRY.

Helmholtz invented the ophthalmometer some fifty years ago; but his instrument was very crude, and it was not until nearly thirty years later, when Javal and Schiötz made alterations and improvements in the instrument, that it was able to be used generally in the testing room. And it was not until 1889 that they brought the ophthalmometer into its present model, which is now as near perfection as it is ever likely to be—except, perhaps, in some minor details.

There are several ophthalmometers made; but they possess, in my opinion (and I have used several), no advantage, when compared with the latest model of the Javal-Schiötz instrument, which has lately been made by the British Optical Company.

The ophthalmometer is an instrument which enables the refractionist to determine the amount, the axis, and also the character of the Astigmatism, without the help or interference of the patient; and these data are obtained in the most expeditious manner possible, and without the aid of a darkened room, or the instillation of cycloplegics.

The ophthalmometer should never be looked upon as a substitute for the subjective method of testing; but rather as a guide and check, so that the subjective examination may be conducted upon a logical basis.

The information afforded by the ophthalmometer is much more reliable than that given by the retinoscope, or any other

objective method; but the instrument is not so universally adopted as the skiascope, because its field of usefulness is limited to corneal Astigmatism.

The special advantages of the ophthalmometer (which constitute it the most valuable auxiliary of the trial case at the disposal of the refractionist) are as follows:—

1. It tells the observer whether there is any Astigmatism present or not; and, if there is, the exact axis in which to place the correcting cylinder, and also the amount of corneal Astigmatism present. (All will agree that it is a great thing to know beforehand the amount of the Astigmatism existing, and the direction of the two principal meridians.)

2. The first glance at the *mires* (a French word, meaning "target") reflected on the Cornea indicates whether the Astigmatism is regular or irregular.

3. It reduces the cases in which it is necessary to use atropine to a minimum.

This instrument will be found invaluable in cases of young children with Astigmatism, or in cases of very slight degree; as the amount and axis can be ascertained independently of the patient's answers, or of the patient's accommodation—which is more important still.

The principle on which the ophthalmometer is based is the measurement of the radii of curvatures of the Cornea, by means of reflected images, which are viewed through a telescope—the object being more to ascertain the difference of curvature in the several meridians, than to obtain the exact measurement in any direction.

The construction of the ophthalmometer is based on the following optical principles:—

A ray of light traversing a plate of glass having parallel "faces," will pass through without deviation, if it falls perpendicular to the plane of this plate; but if it falls obliquely upon it (as shown in Fig. CXXX. 1), it undergoes lateral deviation, and emerges in a direction parallel to that of the

incident ray. Therefore, an eye situated behind the glass plate, sees the luminous point B in the direction of the prolonged emergent ray (at B′); and thus point B′ is apparently displaced laterally, the amount increasing with the obliquity of the incident ray. If two plates of equal thickness are used, instead of one, and placed one above the other, two images will be seen, each displaced a little to one side.

The instrument used consists of a small telescope (T Fig. CXXX. 2), the axis of which coincides with the plane separating the two glass plates (PP′, PP′). If we look at an object (B), and turn the plates till two are seen (B′, B′) touching each other, the size of the image of B will be equal to the distance that the two objects are displaced respectively to the

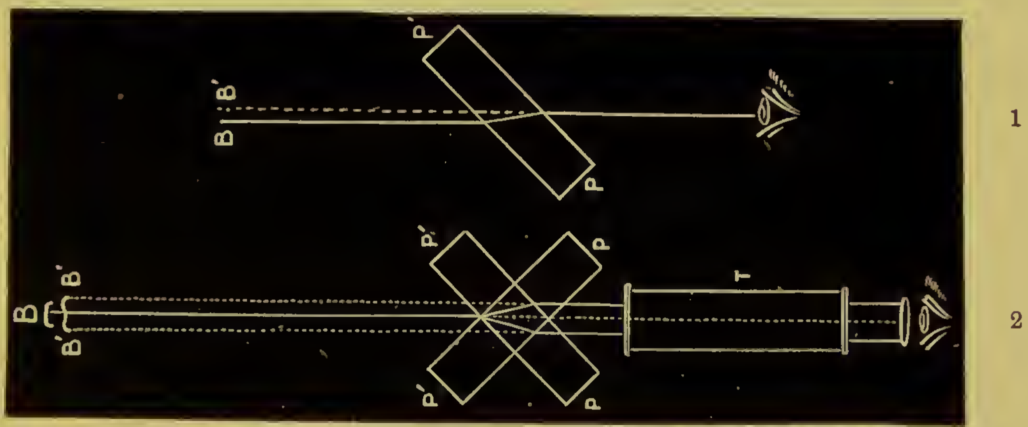


FIG. CXXX.

right and left sides. Having in this way ascertained the size of the reflection, it is an easy matter (if we know the size of the object reflecting the light and its distance from the eye) to calculate the radius of the curved surface.

The ophthalmometer of to-day is based on the foregoing plan, but the improved manufacture and design have reduced the readings of the different measurements to a mechanical process—so that the difference of curvature of the Cornea in the various meridians is recorded in dioptres; and also the targets or reflecting objects employed are so designed that, by noting the amount of overlapping or separation, the degree of

Astigmatism (*i.e.*, the difference in curvature of the corneal meridians) can be seen at a glance.

The instrument now employed to accomplish this result is illustrated in Figs. CXXXI. and CXXXII., and consists of the following devices :—

(*a*) A vertical support carrying a telescope; the optical combination of which consists of two doubling prisms, set in

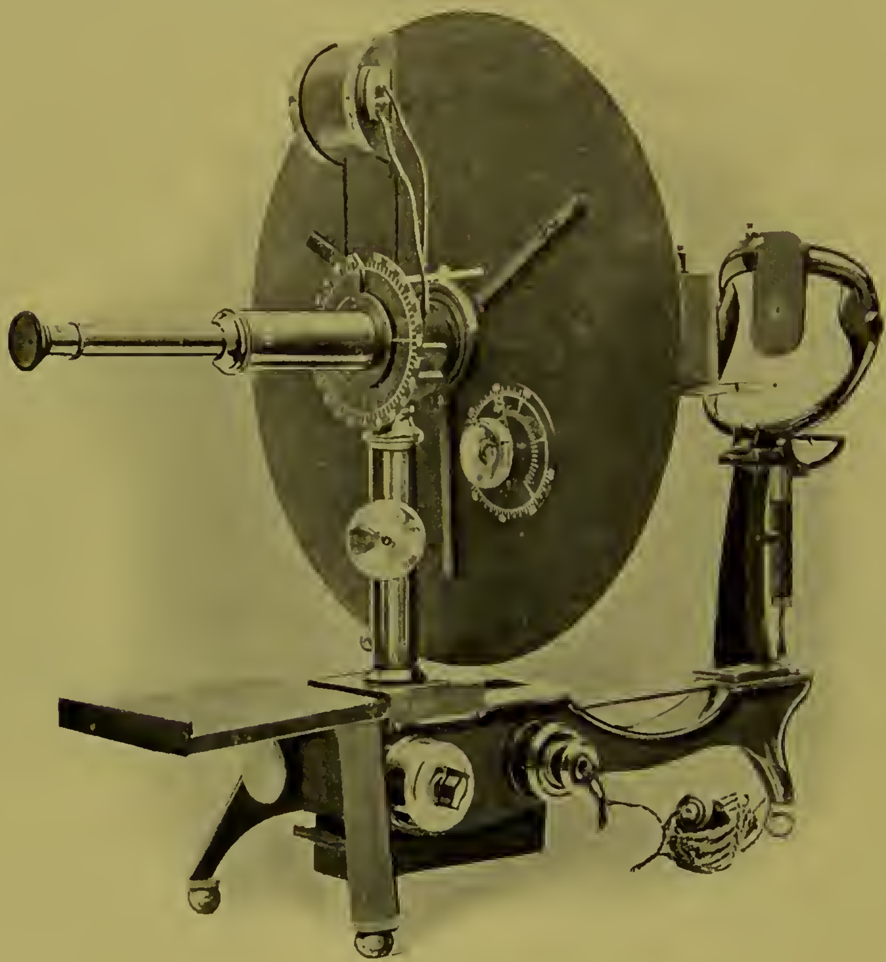


Fig. CXXXI.

such a manner as to double the image reflected on the Cornea; and two achromatic objectives, used in combination with a Huygenian eye-piece, which greatly magnify the reflected image.

(*b*) A graduated arc, to which are attached two sliding mires, or targets, which are operated by a gear movement at the back of—

(*c*) A large metal disc, attached to the telescope, immediately behind the arc.

(*d*) Focussing adjustment by means of a rack and pinion on the sliding table of base.

(*e*) Perpendicular adjustment of the telescope, by a rack and pinion on the upright.

(*f*) Rotating joint, for lateral movement of the telescope.

Fig. CXXXII.

(*g*) A scale on the back of the large disc, graduated to correspond to the graduations of the arc; and an index with three pointers, to show the relative positions of the mires, and to indicate the measurement of the corneal curvature.

(*h*) Small dial at the back of the telescope, to read the direction of the two principal meridians of Astigmatism.

(*i*) Adjustable chin-rest, operated by means of a milled head from the operator's end of the base. This is a perforated

design, which is more sanitary, as it prevents the accumulation of moisture. The mechanism for adjusting the chin-rest is such that it can be raised or lowered with ease and rapidity.

(*j*) A removable eye-shield, containing an artificial normal cornea on one side; and on the other, an astigmatic cornea, which rotates, so that the Astigmatism can be shifted to any axis; forming excellent practice.

(*k*) Illuminating apparatus, either electric light or gas attachment; the former being preferable, for reasons to be stated hereafter.

The writing-pad at the back of the base will be found convenient for writing down the readings of the instrument. There is a simple screw-locking arrangement, whereby the instrument can be fixed in any desired position; which prevents the Ophthalmometer from shifting during the examination.

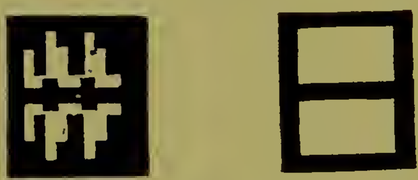


FIG. CXXXIII.

The *mires* or targets generally used are the "steps" and "parallelograms" (see Fig. CXXXIII.); and although there are many modifications of these on the market, there are really none possessing any distinct advantage over these. Every "step" is of such a size that an overlapping of each one represents 1D. of error, so that the degree of defect can be read off by noticing the amount of overlapping or separation of these "mires" as well as ascertaining the degree mechanically —in this way, one method confirms the other.

The illumination used in ophthalmometry should be good, and equal in every position, no matter in what meridian the mires may be rotated. In order to obtain this equal illumination, the mires are made of porcelain, and are trans-illuminated by means of small incandescent lamps placed

behind each of them. This not only ensures a perfect illumination in every position of the arc, but also does away with the unpleasantness caused by heat, when the illuminant is close to the patient's head. These mires are, therefore, much to be preferred. It is obvious that this trans-illuminated attachment can only be used with electric light, and not with gas, which must be attached to the head-piece.

It may be thought by some of my readers that too much space is devoted to the construction of this instrument; but this is not the case. This description is given in order to facilitate the manipulation of the ophthalmometer, and beginners will appreciate these remarks at the first attempt they make in the use of this instrument.

There are one or two points to be considered before explaining the method of using the ophthalmometer; which are as follows:—

1. It is in the use of this instrument that Astigmatism "with" and "against the rule" plays an important part. When it is "with the rule" it is necessary to subtract 0·50 from the ophthalmometer reading; and when it is Astigmatism "against the rule," 0·50 must be added to the amount thus found. The explanation of this is, that in Astigmatism with the rule, the lenticular Astigmatism is in the same meridian as the corneal; but it is of the opposite kind, and usually amounts to 0·50. Consequently it neutralizes that amount of the corneal Astigmatism; for which reason you deduct 0·50 from it. On the other hand, if the Astigmatism is against the rule, the lenticular Astigmatism is also in the same meridian as the corneal; but it is of the same kind, and generally amounts to 0·50—so that you must add this to the amount indicated by the ophthalmometer. As the degree of lenticular Astigmatism is not constant, this alteration of 0·50 D. must be considered as approximate only; the actual allowance more or less, being found by trial afterwards, when testing the visual acuity at the distance types.

2. The first glance at the mires reflected on the Cornea, as the arc of the instrument is slowly rotated, is sufficient to indicate the presence or absence of Astigmatism. Irregular or regular Astigmatism is distinguished easily; as in the first case, the images of the mires are distorted, and are not of the same size; whereas, in the latter case, the mires are not deformed, and are of the same dimensions; also the two principal meridians are 90° apart.

3. As in the subjective method of testing, only the two principal meridians (*i.e.*, those of least and greatest Ametropia) are considered; the intermediate directions being disregarded entirely.

4. If the images neither overlap nor separate, on rotating the dial, it shows that there is no corneal Astigmatism at all; or, in other words, that the curvatures of all the meridians are the same.

5. As in using the ophthalmoscope, when examining the Cornea with the ophthalmometer, the observer should keep both his eyes open.

DIRECTIONS FOR USE.

Let the patient place his chin on the chin-rest, with his forehead pressed firmly against the head-piece, the head being kept perfectly upright, which is essential.

Adjust the height of patient's head, by raising or lowering the chin-rest, by means of the thumbscrew at operator's end of the base of ophthalmometer; until both of his eyes are on a level with the white marks which will be noticed on the vertical sides of the head-piece.

Turn the eye-shield in front of the eye not being examined, and then switch on the electric light, and focus the telescope until you get the patient's Cornea distinctly into view; when you will notice a double image of the mires reflected in the Cornea, as in illustration Fig. CXXXIV. No heed need be taken of the two outer images; only regard the central ones.

You focus the instrument by means of two milled heads, one of which raises or lowers the telescope; and the other moves it nearer to or further from the observed eye, as desired. The arc of the instrument should be kept horizontal at the start; and the plus (+) pointer will indicate 0. In order to sight the telescope, you look through the tranverse slit in the dial.

By means of the milled heads on the back of the large dial, approximate the two central images, by drawing them

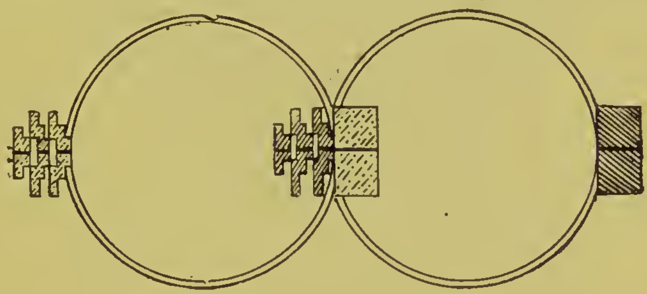


Fig. CXXXIV.

apart, or bringing them together until the inner edges just touch; that is, you make the "steps" just meet the inner sides of the "parallelograms," so that they appear as in Fig. CXXXV.

When this is done, you have one of the principal meridians; and the other is now easily located, being, of course, situated at right angles to the first.

When the primary position is reached, the central horizontal lines of the mires would be continuous. So as to obtain this, it may be necessary to turn the arc to any position within 45° of the horizontal; but *never* on any account turn the plus pointer more than 45° on either side of the zero mark on the scale; as if you do, the instrument will read Astigmatism "with the rule," when it is really "against the rule"; and Astigmatism "against the rule," when it should read "with the rule." So it should be remembered that the primary position may be anywhere within an angle of 45° from the horizontal.

For the benefit of those of my readers who do not thoroughly understand what I mean by the expression

"primary position," I will explain. This position is nothing more or less than the point at which the central horizontal lines of the mires become coincident, and form one continuous

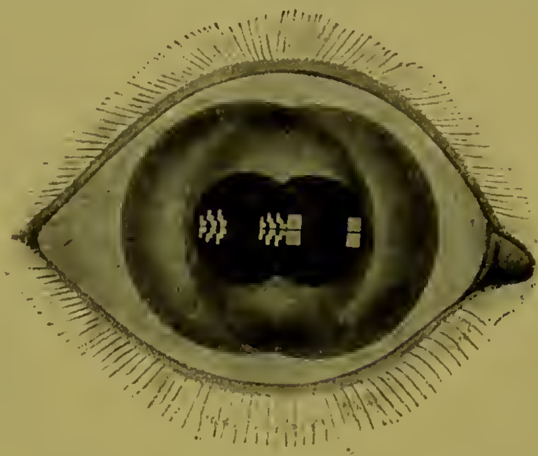


Fig. CXXXV.

line; and in the event of there being any Astigmatism present, this indicates the direction of one of the principal meridians.

The secondary position, as explained before, is always at 90° from the primary position in regular Astigmatism.

If the central horizontal lines of the mires are continuous when the plus pointer registers 0, this is the primary position, and it is unnecessary to go any further; but should they *not* be continuous at this position, then rotate the arc slowly, by grasping the telescope firmly just behind the dial, towards 135°.

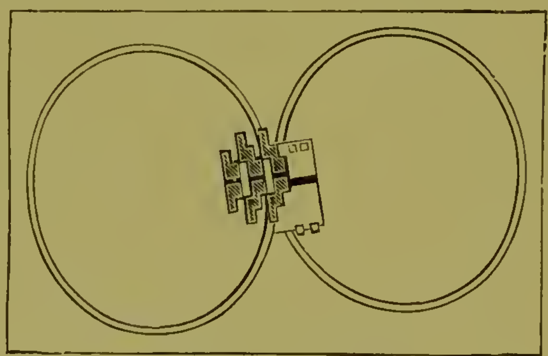


Fig. CXXXVI.

Should they not become continuous at any point between zero and 135°, then turn back again to 0, and rotate the arc towards 45°, when the lines must necessarily become continuous *before* reaching that meridian, as was explained just now.

Before approximating the mires, it should be seen that the two pointers, marked "S.P." and "P.P." respectively, fit exactly one over the other. Rotate the dial slowly 90° from the primary position. Whilst doing this you will notice that the central lines of the mires become broken, as in Fig. CXXXVI.; but you must continue to turn the dial until they again become continuous, when you will have obtained the "secondary position," which will be 90° from the first, if

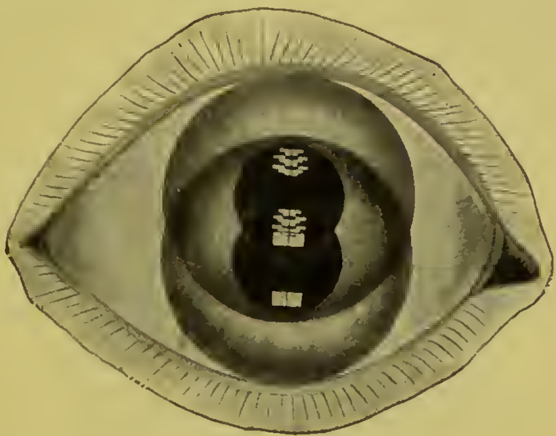


FIG. CXXXVII.

the Astigmatism is regular, and the mires will be seen as in Fig. CXXXVII.

When this position is obtained, lift the secondary pointer (S.P.) so that it forms a right angle to the surface of the scale; and again approximate the mires, so that the inner sides are just in contact.

If, in order to do this, it is necessary to separate the mires (that is to say, if the mires overlap whilst approaching the secondary position), it shows that the Astigmatism is "with the rule." If this is the case, you take the reading of the axis of your cylinder in the secondary position; that is, on the first turning of the dial.

When contact is obtained in the secondary position, place the secondary pointer against the scale, and the difference between this and the primary pointer will indicate the exact amount of the Astigmatism; or, in other words, the

difference in the refraction of the two principal meridians. Fig. CXXXVIII. shows 5D. of Astigmatism.

The plus (+) pointer on the dial behind the telescope shows the direction of the axis, when a convex cylinder is needed; and the minus (−) when a concave cylinder is required, *in all cases.*

If, on turning the dial in order to obtain the secondary position, the mires are seen to separate, and it is necessary to bring them together in order to form the desired approximation, it shows that the Astigmatism is "against the rule"; when

Fig. CXXXVIII.

the reading for the axis of the cylinder is not taken until the dial is rotated back to the primary position; or, in other words, on the second turning of the dial.

If, on rotating the dial of the instrument from the primary to the secondary position, the mires neither separate nor overlap (that is to say, remain stationary), there is no corneal Astigmatism present.

As stated earlier, there is another way of estimating the amount of Astigmatism, besides by the mechanical device of the instrument—by noticing the amount of overlapping or separation of the mires on approaching the secondary position. If the mires overlap *two* "steps," the defect would be 2D. "with the rule"; or if they separated *one* "step," the amount would be registered as 1D. "against the rule."

You ascertain whether the patient is hypermetropic or myopic in the usual way, with spheres; as the ophthalmometer only measures accurately the amount of corneal Astigmatism (which represents fully nine-tenths of all cases of Astigmatism), and the axis of the cylinder, but does not estimate the axial Ametropia.

It is possible to tell approximately whether the Astigmatism of the patient is hypermetropic or myopic, by measuring the curvature of the Cornea. This measurement is obtained by noticing the reading of the small short pointer on the inner scale affixed to the back surface of the dial. If the radius of the curvature of the Cornea is too long, it shows hypermetropic; and if it is too short, myopic Astigmatism.

Example.—If the measurement of the curvature of the Cornea was seven millimetres, it would indicate Myopia; but if it should be 8·3 millimetres, it would show Hypermetropia.

The normal or average measurement of the Cornea of the emmetropic eye is 7·8 millimetres. This measurement should always be taken on the *primary* position. As before stated, you must not rely upon this instrument for ascertaining the kind of Astigmatism, but should *always* find this out by means of spherical lenses.

An important point to remember is, not to re-focus the telescope when turning from the primary to the secondary position; as by so doing you will destroy the accuracy of the results. If, however, it is necessary to raise or lower the instrument, for centring the images, this may be done without interfering with the integrity of the reading.

In Astigmatism, when the principal meridians are exactly at 45° and 135°, the Astigmatism is neither "with" nor "against the rule"; the defect being exactly on the boundary line between the two, as it were. In these cases, the rules given down, as regards "with" and "against the rule," do not always hold good.

Now that the student has had explained to him the essential rules and procedure of manipulating the ophthalmometer, he should experience little difficulty in using the instrument, after one or two practical trials with it. After all is said and done, there is nothing like practice for making perfect; and I firmly believe that, with the theoretical knowledge the reader now possesses, he would have no difficulty whatever in diagnosing a case of Astigmatism with the ophthalmometer, after a few practical demonstrations with the instrument by some one competent in its manipulation.

With the object of elucidating any points that may still be a little hazy to the reader, we will study the following few examples. To make these thoroughly comprehensible, it is necessary to explain exactly what is seen and done in each case, so as to obtain the necessary result.

Case I.—Ophthalmometer reading: Astigmatism "with the rule," 2·00, ax. V. if +, and H. if −.

On viewing the patient's Cornea through the telescope, after focussing it, the double images of the mires are easily discerned, and it is seen that the horizontal dividing lines of the mires are perfectly continuous; and as the arc of the ophthalmometer is horizontal, this is one of the principal meridians. By turning the milled head at the back of the large dial, the mires are made to come together, and brought into contact, and the primary position is obtained. The secondary pointer (S.P.) is now lifted off the primary one (P.P.), so that it forms right angles to the dial. (It is necessary, before the approximation of the mires, to see that the two pointers are coincident). Then the dial is slowly rotated to right angles to the first position, and the dividing lines of the mires are noticed to become broken, and are no longer continuous; so the dial is turned round until they do *become continuous again*, which will be, in this case, when the plus pointer indicates 90° on the scale behind the telescope. Whilst approaching this position, the mires are seen to overlap; this indicates Astigmatism "with

the rule," and it will be necessary to draw the mires apart in order to obtain perfect contact. This is done, and the pointer marked "S.P." is now laid against the scale, and the difference between this pointer and the primary one noted, which is 2D., showing an Astigmatism of 1·50, as we must deduct 0·50 from the ophthalmometer reading, because the Astigmatism is "with the rule"; the mires having overlapped on approaching the secondary position. The plus pointer indicates 90°, and the minus pointer 0 on the scale; so that the defective condition of the eye is expressed as follows:—

1·50D., axis V., if hypermetropic, or H. if myopic Astigmatism.

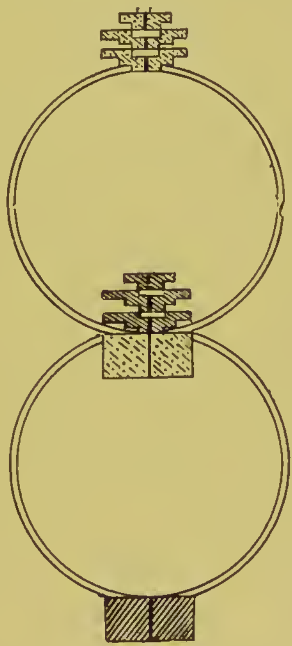


FIG. CXXXIX.

Case II.—Ophthalmometer reading: Astigmatism "against the rule," 2·00, ax. H. if +, or V. if −.

After bringing into focus the Cornea under observation, and shutting off the other eye with the blind, the primary position is found to be horizontal, as the central lines of the mires appear in the same plane without moving the arc from the horizontal position. The mires are separated slightly in this position, and it is necessary to approximate them by turning the milled head at the back of the large dial, so that

the inner edges of both "steps" and "parallelograms" just touch. The secondary pointer should now be lifted off the other, and the dial rotated to right angles to the primary position. During this procedure, the mires are seen to separate, and the lines become broken, and are not in the same plane again until a position 90° from the first is reached.

When this is obtained, the plan is to once more approximate the mires or targets; this time by bringing them together until they assume the shape indicated in Fig. CXXXIX. When this is so, the secondary position is arrived at, and the secondary pointer is placed on the scale; and the difference between the two pointers recorded. In this case the difference is 2·00D., showing a total Astigmatism present of 2·50D., after adding the 0·50 necessary, since the Astigmatism was "against the rule." The reading for the axis of the cylinder is taken from the scale affixed to the back of the telescope; but as the Astigmatism is "against the rule," the reading is taken in the *primary* position, and not in the secondary, as when the Astigmatism is "with the rule"; therefore it is necessary to rotate the dial back to the original position, *before taking the reading of the axis of the cylinder.* In this case this reading will show the plus (+) pointer indicating 0, and the minus (−) pointer 90°. The condition of the eye under examination is recorded thus:—

2·50D., ax. 180° if hypermetropic, or 90° if myopic Astigmatism.

Case III.—Ophthalmometer reading: Astigmatism "with the rule," 5·50, axis 70° if +, or 160° if −.

The primary position in this case is not indicated until the plus pointer, indicating the direction of the arc of the instrument, is turned to the right of zero, to 160°. The necessity of this turning was suspected, as when the arc of the ophthalmometer was horizontal (as it always should be in commencing to test), the central lines of the mires appear disjointed, which showed that the horizontal could not possibly be one of the principal meridians.

When 160° is reached, the mires are approximated, and the secondary pointer lifted to right angles with the dial. Now, by firmly grasping the telescope near the large dial, we rotate the arc 90° to the primary position; and when 70° meridian is reached the mires are again approximated, and the inner sides of the targets made to touch. Now, by placing the secondary pointer against the scale, the amount of the Astigmatism is read off – 5·50D.

In order to approximate them, the mires had to be separated, showing the Astigmatism to be "with the rule"; so that the reading for the axis is taken at the secondary position, and it is found that the plus finger points to 70°, and the minus one to 160°.

The state of affairs, present, then, is:—

5·00D., ax. 70° if hypermetropic, or 160° if myopic Astigmatism.

Case IV.—Ophthalmometer reading: Astigmatism "against the rule," 1·00, axis 15° if +, or 105° if –.

The primary position is not obtained until the arc is rotated to 15°, as indicated by the plus pointer, when the mires are approximated, and the secondary pointer lifted off the primary one.

On turning the arc to 105° the mires separate, and in order to obtain perfect contact they have to be brought together, when the secondary pointer is placed against the scale, and the amount of Astigmatism read off, which is 1·00D. The arc has now to be rotated back to the primary position again before the axis can be read off, because the Astigmatism is in this case "against the rule."

On the primary position being reached, the plus pointer indicates 15°, and the minus one 105°; so that the condition present, after adding the customary 0·50, when the Astigmatism is "against the rule," would be:—

1·50D., axis 15° if hypermetropic, or 105° if myopic Astigmatism.

If the refractionist is astigmatic himself, he should wear his correction; but in the event of his defect being simply Hypermetropia or Myopia, this may be overcome by means of an adjustable eye-piece in the telescope. If the observer is hypermetropic, turn the eye-piece to the left, and when myopic, to the right.

The eye-piece should be turned as far as possible to the left, or as little as possible to the right, provided the Cornea of the patient is still distinct; for the same reason that we give the strongest convex lens to a hypermetrope, and the weakest concave glass to a myope, when prescribing for such cases.

On rotating the arc from the primary to the secondary position, it is better to turn the dial from right to left; for the reason that it leaves the scale and thumbscrew on the back of the dial, within easy reach of the operator.

It will sometimes be found that the patient will be unable to keep his eyes in a fixed position during the examination. This difficulty may be easily obviated by fixing over the end of the telescope a piece of cardboard an inch or two in diameter, and letting the patient look at this, which will relieve the nervous tension.

In summing up the usefulness of the ophthalmometer, it may be said that it tells us whether the Astigmatism is "with" or "against the rule," the exact amount of Astigmatism, and also the positions of the meridians of least and greatest Ametropia.

This instrument is useful even in cases of simple Hypermetropia and Myopia, as it proves, beyond a doubt, the absence of Astigmatism—a most important point to be decided upon—and all this information is obtained without the co-operation of the patient.

CHAPTER XVIII.

INFERENCES TO BE DRAWN FROM THE TEST CHARTS ALONE.

Many refractionists, including those of several years' standing, do not understand (or if they do comprehend, do not appreciate) the indications given by the patient's acuity of vision, beyond the mere fact that the patient's sight was not so good as it should be, were the refractive condition of the eye perfect.

For this reason, then, this chapter is devoted to pointing out the conclusions that may be drawn from the use of test types alone, without the application of lenses; so that when the patient's visual acuteness is once ascertained, the refractionist may derive some definite information respecting the case he has in hand.

In Chapter IV. it was shown how to record the visual acuity of a patient; explaining the meaning of, for example, $\frac{6}{6}$, and saying that it implied that the patient, whilst sitting at six metres from the test types, read the line on the distance test chart which should be discerned by the emmetropic eye at that distance—in other words, that the visual acuity of the patient was normal.

But if the reader will refer to the chapter in question, he will also notice that it states that a perfect visual acuity is no criterion of a normal refractive condition. If, then, a patient has an acuteness of vision equal to $\frac{6}{6}$, what is the refractive condition present?

Obviously it can only be one of the two things—either Emmetropia or Facultative Hypermetropia; that is, Hypermetropia which is neutralized or corrected by the patient bringing into play his accommodation.

If the patient saw $\frac{6}{18}$ or $\frac{6}{30}$, as the case may be, it would indicate any condition excepting Emmetropia; it would also show, if the patient was hypermetropic, that his accommodation was not very active.

A patient may be considered as being practically emmetropic if he can see $\frac{6}{6}$ distinctly, and read Jaeger's or Snellen's No. 1 reading type with a good range. It is impossible for such a person to be myopic; because, if he were, he could not see $\frac{6}{6}$; but he might be hypermetropic, using his accommodation—as such a patient, if young, although ametropic, might see normally.

If a patient is over forty years of age, and has a visual acuity of $\frac{6}{6}$, yet is unable to discern Jaeger's or Snellen's No. 1, unless he holds it far from his eyes—and possibly may not be able to read even the larger types distinctly—this patient is presbyopic.

If patient holds the reading card very near to his eyes, in which position he can read the smallest type, but cannot see the distance chart well, excepting, perhaps, the very largest letters, he is myopic.

If a patient can only discern the largest types on the reading chart, and the smaller lines, if seen, are very indistinct, whilst the distant vision is also impaired—the patient is either hypermetropic (when the Ciliary muscle is so weakened as not to make an attempt to overcome it) or has some form of Astigmatism.

In young patients the former hypothesis may be excluded, as the accommodation in such cases would be sufficient to correct the defect partially, if not to overcome it entirely. But in those over thirty years or so, the patient could have either Manifest Hypermetropia or Astigmatism; as after about this

age the accommodation would be too weak to disguise the Hypermetropia.

If a patient is under forty or forty-five years of age, and can only see the largest of the reading types, but at a distance can read $\frac{6}{6}$, he has paralysis of the accommodation. This is corrected by placing in the trial frame about + 3D. sphere; when the patient will be able to read J. No. 1 or Sn. No. 1 easily. If this is so, the paralysis is proven.

If a patient has very poor distant vision, and is able to see the smallest reading type, but on measuring the amplitude of accommodation it is found that he possesses less accommodation than his age and apparent refractive condition indicate, the opposite condition to that just mentioned is present—viz., Spasm of Accommodation. The correction for this defect was described in Chapter XIII.

If, on looking at the astigmatic lines, the patient sees some blacker in one direction than in another, he is astigmatic, provided that his accommodation is at rest.

If a patient sees better than normal (say, for the sake of example, $\frac{6}{5}$ perfectly), he is sure to be hypermetropic—you can exclude all other forms of Ametropia—because only a hypermetropic patient can exert his accommodation, when viewing distant objects, sufficiently to see better than an emmetrope.

In a case like this just mentioned, the best plan in testing is immediately to place before the eye about + 3 or + 4D., to paralyse or tie up the accommodation, and then gradually neutralize it with weak minus lenses (as was fully explained in the chapter on Hypermetropia), as there can be no doubt as to the existence of this defect.

The reader may wonder why patients who can see perfectly should come to have their eyes tested. The reason is that although the accommodation is sufficient to overcome the Hypermetropia at a distance, it is insufficient to meet the excessive demand brought on by reading or close work; so

that the patient comes to the refractionist with much the same tale as a presbyopic patient would—viz., that he is unable to read comfortably for any length of time. But bear in mind that in this case the cause of trouble is the Hypermetropia; so that it must be corrected fully—and give lenses for constant use.

CHAPTER XIX.

RETROSPECT.

I GIVE this recapitulation (at the risk of being accused of unnecessary and tedious repetition), feeling certain that the reader will greatly benefit by the further perusal of these most important points, which not only include those already given down previously, but, in addition, many other matters which have not yet been mentioned in these pages.

The anatomy of the eye, in a nutshell, so to speak, consists of the orbit, lined by the aponeurosis; in which the globe of the eye rests, and from the posterior of which spring the muscles governing the movements of the eye.

The eyeball itself is made up of three layers, or coats:—

The Sclerotic and Cornea;
Choroid, Iris, and Ciliary body; and
The Retina;

in which are contained the Aqueous Humour in front. Then just behind the Iris comes the Crystalline Lens; and behind that again, enclosed in the Hyaloid Membrane, is the Vitreous Humour.

The Dioptric or refracting system of the eye consists of these three humours, together with the Cornea.

The Optic Nerve enters the back of the eye, towards the nasal side, and, at its entrance, is perfectly insensible to light. A little way (about one-tenth of an inch) to the temporal side

of this blind spot (papilla) is the macula lutea, or yellow spot; this is the point of most distinct perception on the Retina, which is an expansion of the Optic Nerve.

The motor muscles are six in all, four of which are called recti or straight muscles, and may be enumerated as follows:—

The internal, external, superior, and inferior; situated respectively to the nasal and temporal side of the globe, and above and below the eyeball. The fifth and sixth muscles are the superior and inferior oblique.

The size of the emmetropic eye is very much the same in all men; any difference observable in this respect being due to the extent to which the eyelids are opened.

Lenses are of two principal classes—spherical and cylindrical; and these may be of two kinds—convex and concave. The spherical convex and concave are again divided into three varieties of each.

Plano-convex or concave;
Bi-, or double, convex or concave;
Periscopic convex or concave.

Cylindrical lenses, however, are always of the plano variety.

The optical centre of a lens is that point at which both the surfaces of the lens are parallel, and in accurately coned lenses it should correspond to the geometrical centre. A ray passing through the optical centre does so without deviation or refraction, and is called the principal axis.

The secondary axes are rays of light which cross the principal axis at the optical centre of the lens. The displacement these rays undergo is so inconsiderable as not to be noticed.

All rays of light in nature are divergent, but those coming from a distance of twenty feet or more (infinity, abbreviated ∞) are considered, for practical purposes, as being parallel. Rays are convergent only after traversing a convex lens, or reflected by a concave mirror.

Errors of refraction are caused either by an under- or over-development of the eyeball. All babies are born hypermetropic, and the eyes do not assume their natural size until about the sixth year of life. If the growth of an eye is retarded in any way, the result is Hypermetropia; but should the eyeball grow too much, Myopia results.

An error of refraction is that condition of the eye when the Retina is not situated in the focus of the dioptric system, and this condition is known as Ametropia. When the Retina is exactly in the focus of the refractive Media, the condition is called Emmetropia. The two principal forms of Ametropia are Hypermetropia and Myopia.

The correction for Hypermetropia is the strongest convex lens which makes the distant vision normal. You use convex glasses because the hypermetropic eye is adapted for convergent rays; and as convex lenses are thicker in the centre, rays of light, after passing through them, are convergent.

In Hypermetropia, and in any other anomaly of refraction of long standing, it is sometimes impossible to obtain a visual acuity of $\frac{6}{6}$. In these cases the refractionist must be content with the best results he can obtain.

If, in testing for Hypermetropia, you should over-correct slightly, for some ulterior reason, always caution your patient that the glasses may not be very comfortable at first; and tell him to persevere in their use. This will save you from a good deal of unpleasantness, and the patient from any misgivings he might otherwise have entertained about the accuracy of your prescription.

If the total amount of Hypermetropia should be ascertained—that is, the latent as well as the manifest error—the full correction cannot be given. It is customary to prescribe for *all* the manifest, and about one-third of the latent defect.

Hypermetropia may be distinguished from Emmetropia by holding a weak plus lens before the eye. If the vision at

a distance is not altered, or if it is improved, the condition present is Hypermetropia; but if the vision is impaired, the patient is emmetropic, provided that the visual acuity is normal without glasses.

The correction for Myopia is the weakest concave lens which affords best vision. Concave lenses are used in cases of Myopia, because the "short-sighted" eye is adapted for divergent rays; and rays of light, after passing through a concave lens, are diverged.

In prescribing for Myopia, it is best, after finding the lens that brings the vision up to the normal standard, to reduce it until the patient can only see $\frac{6}{9}$; as in this way one keeps on the safe side, and there is less possibility of an over-correction being given.

In Myopia of 3D. or under, when the accommodation is entirely gone, or is very weak, *plus* lenses should be given for reading purposes. Never allow a myope to read close to the eyes.

The seat of Astigmatism is generally in the Cornea. The two principal meridians are always situated at right angles, if the Astigmatism is regular.

The object in testing for Astigmatism is to make the patient see lines equally well in all meridians on the chart; or, in other words, to neutralize the inequality of the curvature of the Cornea by means of cylindrical lenses. As long as the lines on the chart are equally distinguished, no matter how indistinct they may be, the Astigmatism is corrected. Do not prescribe cylinders unless they are really of benefit to the patient.

If a weak cylinder is apparently required, rotate its axis to right angles to that at which it appears to be wanted, and if the vision is not seriously impaired, the cylinder is unnecessary.

Before taking a cylindrical lens out of the trial case, a competent refractionist should know, within 5° or so, the meridian in which to place the axis in the trial frame.

In Astigmatism, the cylinder, if once obtained accurately, never requires altering. Any alteration necessary for reading, for instance, is made in the spherical part of the combination.

The best size lines to select, when testing for Astigmatism with the Astigmatic Dial, are those which can be seen by an eye possessing about one-half the standard visual acuity.

If the patient is undecided as to which of two lines at right angles to each other on the Astigmatic Chart is the darker, your spherical lens wants altering; increase it if *plus*, or weaken it if *minus*.

In altering the cylindrical power during testing, always so place the axis that, if there is still a difference in the appearance of the lines, those which were originally blackest are still the most distinct. If they are not, your cylindrical axis is incorrectly placed; and you must return to the Astigmatic Chart to find the blackest lines over again.

If, on placing a cylinder before an astigmatic eye, with its axis at right angles to the blackest lines, the Astigmatism is made more apparent, instead of improving it, rotate the axis to the opposite meridian, 90° away. Should this have the desired effect, and reduce the Astigmatism somewhat, increase the power of the cylinder, leaving the axis in this new position. But, on the other hand, should the cylinder, axis in this direction, also make the defect worse, then a cylinder of opposite kind to the sphere must be used, placing the axis in the original position; that is, at right angles to the direction of blackest lines on the chart.

In low degrees of simple hypermetropic Astigmatism, where it is difficult to locate exactly the axis for your cylinder, a good plan is to make your patient artificially myopic with a convex spherical lens, when the meridian of blackest lines will often be pointed out at once by the patient. Of course, the correction will have to be transposed.

Drawing together the lids is frequently a symptom of

myopia; but this is not infallible, as it is also a sign of hypermetropic Astigmatism.

Irregular Astigmatism may sometimes be remedied by means of the Stenopaic Slit or Pinhole Disc, with or without the combination of Lenses.

In simple myopic Astigmatism, if the visual acuity is brought up to $\frac{6}{6}$, a good plan is to add + 0·25 or + 0·50 sphere, so as to be on the safe side. In very slight degrees of simple myopic Astigmatism—of, say, under 1D.—reverse the axis of the cylinder, and use a plus one instead.

The reading corrections given for the various refractive errors do not hold good after Presbyopia has set in. At this period the plan in prescribing the reading correction is to add to the patient's distance glass the approximate presbyopic correction.

The correction for Astigmatism, even when most accurately fitted, is not always perfectly satisfactory at first. A common complaint is that the ground does not appear level, and also that when going up or down stairs the patient cannot clearly see where to place his feet. Another complaint which the refractionist will probably hear is that with the correcting glasses, patient sees a square object as having uneven sides; the top and bottom of the page of a book, for instance, being of unequal width. All these unpleasant effects will disappear as the patient becomes accustomed to his new correction.

Never give more than + 3D. to a presbyope for reading at thirteen inches, provided there are no complications.

In testing for Presbyopia, add the same plus lens to *both* eyes *at once.*

The first step in testing a patient for glasses (after having gone through the ordeal of listening attentively to the patient's complaints), is to ascertain his visual acuity without glasses, trying one eye at a time.

The visual acuity is expressed in fractions—the numerator representing the distance at which the patient is sitting from

the chart, and the denominator the smallest line of letters which the patient can distinguish at this distance. Six metres (twenty feet) is the best distance at which to hang the chart from the patient, but on no account should it be placed nearer than three metres (ten feet).

Be sure that you have an even illumination over the test types during the examination. Either daylight or artificial light may be used, but the latter is the more satisfactory.

If at any time you are in doubt as to the accuracy of your test, on account of your patient's vacillating answers, spherical lenses can be prescribed temporarily, even if cylinders are called for.

Always begin testing, in any case, with convex lenses.

If a patient sees as well at a distance with a convex lens as without it, that lens is required, and cannot be too strong.

When convex lenses are necessary for distance, pile them on as much as possible.

Concave lenses are only to be used when the weakest convex makes the vision worse.

Only a hypermetrope will be able to see as well with a convex lens, at a distance, as without it.

If no indication is given with spherical lenses as to what kind of cylinder may be required, always start with plus cylinders.

Never, on any pretext, test a patient for close work before ascertaining his refractive condition at the distance tests first.

Always, when patient's accommodation will allow of it, give the distance glass for constant use.

Do not make your patient nervous. Never tell any one that they are likely to go blind; but, should you suspect anything wrong, which cannot be remedied by the proper application of glasses, immediately send your patient to the oculist.

A patient of mine, some time ago, told me that a charlatan called upon her, and endeavoured to persuade her to buy a pair of glasses. She hesitated, wishing to see her optician; but the

pedlar, noticing her hesitation, said to her: "You know what Dr. Johnson remarked about bad eyesight—namely, that a blind person is a living corpse," etc. It is unnecessary to add that the charlatan effected a sale.

A competent refractionist should suit a patient without resorting to any tricks.

In Astigmatism of long standing, it is sometimes impossible to obtain a perfect visual acuity with the correcting lenses owing to want of practice in accurate perception of the Retina; in which case, if the glasses are worn constantly, the vision often improves.

In testing, should a patient miscall any of the letters, never contradict him; allow him to find out his mistake himself, when his sight is properly corrected.

Never take it for granted that a patient has good sight simply because he tells you so—find this out for yourself.

In some cases of Anisometropia, when the two eyes differ to a great degree—one eye being affected only slightly, whilst the other is practically blind, or nearly so—then the better eye should be corrected as much as possible, and the bad eye left alone, after it is ascertained that this one is too far gone to be benefited by correcting lenses.

If a case comes before you which you consider to be beyond the domain of the refractionist, and in the province of the surgeon-oculist, do not hesitate to send the patient to one—in fact, if you did not do so, you would not be doing your duty, either to your patient or yourself.

In all cases of muscular insufficiency, the cause should be ascertained and removed. Nature will do the rest.

When Strabismus is being corrected by prescribing spherical lenses, the *full* correction must be given, to be worn constantly.

In Convergent Strabismus, by giving convex lenses you will diminish the convergence; and in Divergent Squint, by prescribing concave lenses you will relieve the external Rectus.

A prism is useful in some cases of Paralytic Squint, to counteract any Diplopia resulting from this condition. They are also occasionally necessary for exercising the weak muscles, in addition to the correction of the refractive condition of the eye; but not very frequently.

Glasses should never be given to an aphakic patient, until at least a couple of months after the operation for Cataract. As the accommodation is entirely lost, in this defect, owing to the Crystalline Lens being absent, a different lens is necessary for each employment of the patient requiring a different focal distance.

Asthenopia is a word used to designate weakness of the ocular nerves, due to some cause, either errors of refraction or general debility. In the first case, prescribe the correcting lenses. In the second, the patient's constitution requires building up; and, sometimes, weak convex lenses are necessary for reading meanwhile.

After diphtheria, influenza, or any other complaint which produces general weakness, low-power convex lenses may be required for reading, owing to the temporary paralysis of accommodation; but they may be discarded after the patient's strength is regained.

The near point should always be ascertained; both before testing and with the correction before the eyes.

The near point (P.P.) represents in centimetres or inches the patient's amplitude of accommodation, which is convertible into dioptres by dividing the centimetres into 100, or by dividing the number of inches into 40.

The range of accommodation is the distance between the far and the near points.

The amplitude of accommodation is the effort necessary to accommodate the eye to its near point.

The punctum proximum is always further from the eyes in Hypermetropia, and closer to them in Myopia, than it is in Emmetropia.

Blepharitis, Conjunctivitis, and other affections of the eyes, which are not diseases, but the effects of uncorrected refractive errors and which, however, may often become infectious diseases if neglected—may be relieved by prescribing a simple salt, or any antiseptic lotion, resting the eyes for a few days, and, finally, by correcting the cause.

Spasm of the Accommodation is often overcome by the paralysing method of sight-testing.

The static refraction of an eye is, when the accommodation is not exerted. The dynamic refraction is, when the Ciliary muscle is brought into play.

Fig. CXL.

A ready method of determining between a diseased eye and an error of refraction is by means of the Pinhole Disc (Fig. CXL.). When using it (which should not be unless there is some reason to suspect the case to be other than an ordinary error of refraction), the best way is to allow the patient to hold the disc in his hand, and place it before the eye himself; as otherwise you will experience considerable difficulty in obtaining the desired information. If the patient's vision is improved by looking through the Pinhole Disc, the case is an error of refraction; but if vision is not improved by the disc, the case is a disease, and cannot be corrected by means of lenses.

When using the Stenopaic Disc, the meridian in which the patient sees the letters best is the least ametropic—and shows the direction of the axis of the correcting cylinder, if any.

Stenopaic spectacles are often very useful in some cases of corneal opacities; and also in Conical Cornea—which is a bulging forward of the Cornea, producing deep Myopia—when combined with concave lenses, they are of some use.

Strong concave glasses, obscured except at a small central

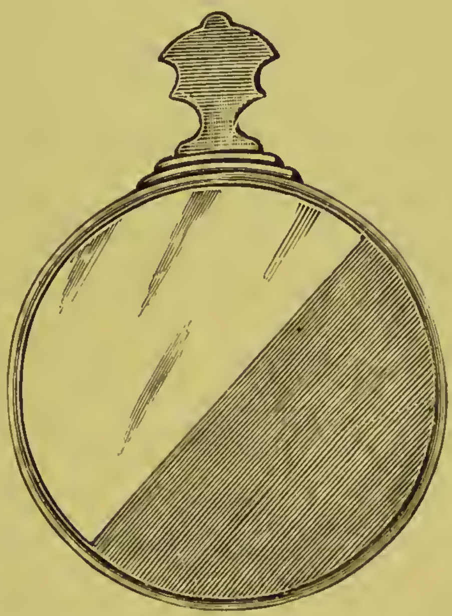


Fig. CXLI.

aperture, forming a pinhole disc, are also useful in this condition.

The half-ground glass (see Fig. CXLI.) is used to find out the relative sensitiveness of the Retina. It is also useful in cases of Hemianopsia and similar defects of the Retina. It is not a very satisfactory disc to use, owing to the fact that it should cover exactly one half of the pupil whilst before the eye, and that, in turning the disc round to test different parts of the Retina, it is liable, in some positions, to entirely cover the pupil, unless the trial frame is perfectly centred, which it is difficult to do.

The existence of binocular vision may be determined by the following experiment:—

Place before patient's eyes a pair of spectacles having a red glass before the right eye, and a green one before the left, and direct him to look at a card placed at a distance, with a coloured glass before each of the letters—alternately red and green. Now, if the patient's right eye is covered with a blank disc, he will only be able to see letters behind the green glass; and if the blank is placed in front of the left eye, only those letters behind the red glass will be visible to the patient. It is evident, then, that if with both eyes uncovered the patient reads all the letters on the chart clearly, binocular vision must exist. And in the event of there being only monocular vision, it is at once manifest which is the "seeing eye." If the letters behind the red glass are seen, the right eye must be used, and should the green letters be read, the left eye is necessarily the "good" one.

Let us, for the sake of example, assume that the letters on the chart form the word "THEORY"; and that in front of the "T" is a red glass, a green one before the "H," and so on, alternately, in front of the others—the letters T, E, R would be visible to patient's right eye, and H, O, Y to the left; consequently, if the whole word is read distinctly, it proves the presence of binocular vision.

Remember that, in transposing, the rule is to take as the spherical lens the meridian of least Ametropia, because if the meridian of greatest defect were taken as the sphere, the spherical and cylindrical powers would differ in sign, and the cylinder would be the weaker of the two; which form would be incorrect.

Cross cylinders are unnecessary; sphero-cylindrical lenses take their place.

When tinted glasses are required, give them as light as possible.

Colour blindness, or Daltonism, is due to paralysis of the fibre of that colour which the patient is unable to recognise. This cannot be corrected, but it is important that this condition should be detected, as serious results would ensue were this defect allowed to go unheeded.

Smoking in excess has a tendency to cause dimness of vision, but absolute blindness is never the direct result of the abuse of this agent. The rational remedy is to moderate the habit.

Bear in mind that to obtain an accurately fitting frame is as important as getting a perfect correction with lenses; and that, without it, the correction of the visual defect, however good, cannot have the desired effect. Always notice the symmetry of your patient's face in fitting a frame, as occasionally it will be found that one eye is set further from the nose than the other, necessitating a specially adapted frame.

Do not try to fit all faces with a "No. 1 eye" frame, obtaining the necessary inter-pupillary distance by altering the bridge, as the bridge would be out of proportion to the frame; but for a larger face use an "00" or "0" eye, and for ladies a "No. 2 eye" frame. For children I prefer the "No. 1 eye," and occasionally a round eye, measuring thirty-eight millimetres by thirty-eight millimetres.

Frames should not be fitted further from the eye than half an inch (or twelve millimetres), excepting in Presbyopia; when they may be placed in any position most convenient for the patient's comfort.

Always recommend "R.B." frames for out-of-door or constant use; as they prevent the lenses from slipping down from their intended position.

Do not put cylindrical glasses into folder frames. For instance, we will assume that you give a cylindrical correction with an oblique axis, and you fit it into a folder. When it is on the face, the lenses may assume a vertical direction; if so, your correction of the refractive condition may be perfect, but the result is a failure.

Also, do not use any new-fangled spring clips where Astigmatism is concerned; as the lenses are seldom placed twice in the same position before the eyes, owing to the frame not being sufficiently rigid.

The amount of light entering the eye is increased by a convex lens, and diminished by a concave one.

The prismatic effect produced by decentring a convex lens inwards, is that of a prism, base in; the reverse holds good in a concave lens.

Single eyeglasses, or "Oxfords," should be avoided.

Lorgnettes are sometimes useful for patients suffering from *deep* Myopia, when it is not advisable to prescribe the full correction for constant use; as these lenses may be fitted into a pair of lorgnettes, and used occasionally, when the patient is desirous of noting any object of special interest at a distance.

In prescription work, always insist that your wholesale optician uses the best lenses and finest workmanship; as sometimes a few pence will make a considerable difference in the way in which a prescription is filled.

If the ophthalmometer and trial case are used in estimating the refraction of a patient, atropine is very seldom, if ever required, even when testing young children.

Do not cover the walls of your testing-room with an array of different test charts, as these tend to confuse the patient. Use one chart, with a perforated dial, as illustrated in the chapter on Astigmatism—which serves for testing any kind of defective eyesight.

Objective tests, no matter how accurate they are, can only remain as auxiliaries to the trial case.

Now, a few words concerning the contents of a trial case which should meet the demands of most refractionists. It should contain the following:—

1 pair each spherical convex lenses, 0·25 to 20D.
1 ,, ,, ,, concave ,, 0·25 to 20D.

1 pair each cylindrical convex lenses 0·25 to 6D.
1 ,, ,, ,, concave ,, 0·25 to 6D.
A few prisms, from 1^{Δ} to 20^{Δ}.
Eight discs, including Stenopaic discs, blank discs, pinhole discs, Maddox rod and double prism, and one red and one green glass.
Three each blue and smoke-coloured lenses—light, medium, and deep tint.
A good adjustable trial frame, and also an ordinary single trial frame.

It is advisable to always keep in the trial case a piece of clean chamois leather for polishing the lenses, as they are easily soiled, although mounted in rings. If an unclean lens is inadvertently placed in the trial frame, the patient imagines that the dimness of vision thus caused is due to the lens being rather too strong or too weak; and mistakes ensue.

A good tool to have handy is a pair, or rather two pairs, of smooth-mouthed pliers; as very often only a slight alteration in a frame is wanted, which can be made with the aid of these, and the frame fitted accurately. In this connection it may be said that in altering the shape of a bridge only the shanks should be re-adjusted.

CHAPTER XX.

CASES.

The following are a few cases from my own Record Book, selected at random, which I think should be of interest to my readers:—

Case 1.—Presbyopia. Mr. D. L., age 45.

History.—Patient complains of difficulty in reading, especially by artificial light. He has never worn glasses; and until lately has always had good sight for reading. O.U.V. = $\frac{6}{6}$.

On holding +0·50 sphere before both eyes (of course, testing each separately), vision is made decidedly worse; showing the absence of any Ametropia. +0·75 sphere before each eye enables patient to read J.1 easily, at a distance of thirty-three centimetres.

Prescription for Mr. D. L.:—

O.U. +0·75, for reading only.

Case 2.—Presbyopia. Mrs. A. W., age 60.

History.—Mrs. A. W. has worn glasses for the last fifteen years or more; but states that her present glasses are now "failing her," and that she cannot read as near to her as she would like to.

On testing the distant vision, it is found to be normal. With +2·50 sphere placed in the trial frame, she can read the smallest type on the reading card quite well.

Prescription for Mrs. A. W.:—

O.U. +2·50, for reading only.

Case 3.—PRESBYOPIA. Mrs. H. A. L., age 43.

History.—This patient just feels the effects of old age; inasmuch as she cannot read well at night, although she has no trouble at all in the daytime. Distant vision is normal, and there is no Ametropia.

+ 0·50 for both eyes is prescribed; to be worn only in the evening, when reading or working by artificial light.

Case 4.—PRESBYOPIA AND HYPERMETROPIA.

Mr. F. W., age 50.

History.—Complains that he has never been able to obtain satisfactory glasses for reading; and also that, after reading for a short time, his eyes begin to ache. Distant vision is also rather dim. The reading spectacles patient has been wearing are + 3D. in both eyes.

On testing the right eye for distance + 2D. is found to give the best results, and brings the vision up to $\frac{6}{6}$. The left eye requires + 0·75 to produce normal vision. The distant correction is placed in the back cell of the trial frame, and the reading type given to the patient; which, of course he cannot see, excepting the larger letters, unless the card is held far from the eyes.

With an addition of + 1·50 before each eye, the patient can read the smallest type very well at thirty-three centimetres; so the prescription for reading is:—

R.E. + 3·50
L.E. + 2·25

and for distance:—

R.E. + 2·00
L.E. + 0·75

At first the patient complained of difficulty in reading with these glasses, on account of the difference in the corrections of the two eyes. He was told to persevere with them; and on his returning, a few weeks later, he said that the glasses were entirely satisfactory, and that it was now "a pleasure to read."

Case 5.—Presbyopia and Hypermetropia.

Mr. H. C. M., age 55.

History.—Has worn glasses for reading for some years, but is not comfortable in them. Is now wearing +3·25 for near work, for both eyes.

On testing the acuity of vision, R.E. V. = $\frac{6}{24}$; L.E. V. $\frac{6}{36}$.

The correction for the right eye, for distance, was found to be + 2D., and for the left + 3D.; which affords a vision of $\frac{6}{6}$ in either eye, but are of no use for reading—so + 2D. was added to the above in each eye.

The prescription given Mr. H. C. M. was:—

For distance	R.E.	+ 2
	L.E.	+ 3
For reading	R.E.	+ 4
	L.E.	+ 5

Case 6.—Presbyopia and Hypermetropia.

Mr. J. D., age 57.

History.—Mr. J. D. says that distant vision is all right, only he cannot read as well as formerly with the glasses he now has, although at first they were very satisfactory. He fancies that they must be getting "too young for him." The glasses he has been wearing are O.U. + 2·25D. Visual acuity equals—R.E. $\frac{6}{12}$; L.E. $\frac{6}{9}$ without any lenses.

Testing each eye separately, the distance correction is found to be:—

R.E. + 1·50
L.E. + 1·00

According to his age, the patient requires for the Presbyopia about + 2·25, which is placed in the front cell of the trial frame before the distance correction; and this is entirely satisfactory for reading purposes. The patient will not wear glasses out of doors; so that only the reading ones are supplied, as follows:—

Prescription for Mr. J. D.:—

R.E. + 3·75
L.E. + 3·25

Case 7.—Presbyopia and Myopia. Mrs. A. C. W., age 55.

History.—This patient has worn glasses for distance for many years, but has never wanted them for reading until just lately, when she has experienced a little difficulty, more particularly by night.

On testing for distance it was found that patient required O.U. – 1D. These lenses are placed in the back cell of trial frame, and in front of them are placed + 2D. for Presbyopia. These are found to be too strong; so they are replaced by + 1·50, which enables the patient to read very easily at the requisite distance.

Prescription for Mrs. A. C. W.:—

O.U. + 0·50, for reading only.

Case 8.—Presbyopia and Myopia. Mr. B. S., age 51.

History.—Eyes became very tired by night; has never been able to obtain glasses for reading, although he has used them for distance ever since he was a child.

The distance test revealed:—

$$\text{R.E. V.} = \tfrac{6}{36}\ \bar{c} - 3{\cdot}50 = \tfrac{6}{9}$$
$$\text{L.E. V.} = \tfrac{6}{60}\ \bar{c} - 5{\cdot}50 = \tfrac{6}{12}$$

—no better vision being obtainable. The patient requires this correction for distance; but for reading wants + 1·75 added to

each eye for the Presbyopia. The distance glasses that the patient was wearing were correct; so that only the reading correction was given.

Prescription for Mr. B. S.:—

$$\left.\begin{matrix} \text{R.E.} - 1{\cdot}75 \\ \text{L.E.} - 3{\cdot}75 \end{matrix}\right\} \text{ for reading only.}$$

Case 9.—PRESBYOPIA AND ASTIGMATISM.

Mrs. C. C. H., age 45.

History.—Required glasses for reading; was now wearing O.U. + 0·75 cyl. ax. V.; which, on testing, was found to be correct.

On combining + 0·75 sphere with the distance correction, patient was able to read J.1 at thirty-three centimetres without difficulty.

Prescription given for reading was:—

O.U. + 0·75 sph. ⊃ + 0·75 cyl. ax. V.

Case 10.—PRESBYOPIA AND MIXED ASTIGMATISM.

Mr. B. H. M., age 50.

History.—Has always had poor sight for distant and close objects; fancies he requires stronger glasses for reading, now that he is getting older. The distance test reveals Mixed Astigmatism of:—

R.E. – 2 sph. ⊃ + 2·75 ax. 70°
L.E. – 1·50 sph. ⊃ + 2·50 ax. 160°

At the patient's age, about + 1·50D. should be added to this for reading. In Astigmatism, the cylinder always remains the same; consequently, the spherical lens requires altering, so the – 2 sphere of the right eye is taken away, and a – 0·50 sphere substituted. In the left eye no spherical lens is required at all, as the presbyopic correction entirely neutralizes

the $-1·50$ sphere before the eye; so that in reality the correction is weakened, and not made stronger, by the advent of Presbyopia in this case.

Prescription for Mr. B. H. M.:—

R.E. $-0·50$ sph. $\bigcirc$ $+2·75$ cyl. 70°
L.E. $+2·50$ cyl. ax. 160°

Case 11.—Paralysis of Accommodation.

Miss R. F. W., age 16.

History.—This patient has lately recovered from a severe illness; she complained now of being unable to read, sew, or, in fact, do any near work. Previous to her illness, she said she had "very good eyes, and could see anything." Her vision at a distance still remained unimpaired. The pupils appeared dilated; and on holding a light before the eyes, they did not appear to respond readily to light.

On testing the distant vision, it was $\frac{6}{6}$ in both eyes, and any convex lens made vision worse; so paralysis of accommodation was suspected, which was confirmed on finding that a +3D. before both eyes enabled patient to read comfortably. These glasses were prescribed for reading, as a temporary expedient, as they were the weakest convex lenses which the needful correction supplied. The glasses had to be changed for weaker ones gradually, as the Ciliary muscle regained its lost activity; and eventually, when the patient had thoroughly recuperated her strength, dispensed with altogether.

Case 12.—Hypermetropia. Mr. D. B. W., age 19.

History.—Mr. D. B. W. came to me, complaining of pain in his eyes, and saying that he required glasses only for reading, as he could see anything at a distance. The visual acuity of the right eye was $\frac{6}{6}$. A weak plus lens made no

difference whatever, showing Hypermetropia. On tying up the accommodation with a plus lens, and reducing it with minus, the lens accepted was +4·50, with which the vision was nearly $\frac{6}{6}$.

With the left eye, patient could read $\frac{6}{9}$, proving at once the presence of Hypermetropia. The accommodation was paralysed with a strong convex lens, and this was reduced with minus lenses until patient could read *nearly* $\frac{6}{6}$, but no better. The difference between the minus and plus lens was +3D.; so that this was the correcting lens. On testing binocular vision, no stronger glass was accepted, without impairing vision; but since the visual acuity with both eyes was $\frac{6}{6}$, it was advisable to give +0·50 sphere to reduce it to $\frac{6}{9}$, on account of the patient having such an active accommodation; which, of course, was the cause of the pain the patient complained of in his eyes.

The following prescription was given for constant wear:—

R.E. +5·00
L.E. +3·50

It is shown, in this case, that it is not advisable to take for granted that a patient does not require glasses for distance, simply because he says so.

Case 13. Hypermetropia. Miss M. R. W., age 18.

History.—Miss M. R. W. has never worn glasses, but complains of weak eyes. The eyelids look irritable and red.

Acuteness of vision of the right eye is nearly normal. A +6D. is found sufficient to paralyse the accommodation; and on reducing with minus lenses (as explained fully in the chapter on Hypermetropia), −2·5 is found to bring the vision up to $\frac{6}{9}$. This glass is quite strong enough; it is not advisable to bring the vision quite up to the normal standard.

On placing $+3 \cdot 50$ in the back cell of trial frame, and then removing the $+6$D., patient reads $\frac{6}{9}$ perfectly, and two or three letters on the six-metre line.

The visual acuity of the left eye is found to be much the same as with the right. We paralyse the accommodation of this eye in the same manner as above, and the correcting lens is found to be also $+3 \cdot 50$.

On testing binocular vision, patient could read $\frac{6}{6}$ nearly, and no stronger glass will be accepted.

So this prescription :—

$$\text{O.U.} \quad +3 \cdot 50$$

was given for constant use, as it was ascertained that patient could read with the distance correction. The patient was told to wear these glasses constantly, and to bathe the eyes with a simple salt lotion for a few days. She returned after one month and reported that the glasses suited admirably; and the weakness of the eyes, of which she had formerly complained, had entirely left her. The inflammation of the lids had also disappeared.

The trouble of this patient was occasioned by the constant strain on the Ciliary muscle in the endeavour to overcome the Hypermetropia, and could only be remedied by correcting the cause.

Case 14.—Hypermetropia. Mr. A. J., age 30.

History.—Required glasses for distance and reading; has never worn spectacles before.

$$\text{R.E. V.} = \tfrac{6}{24}$$

A $+1$D. made vision slightly better; so a $+2$, 3, 4, and 5D. were successively placed before the eye, until the one was obtained that gave normal vision. With $+5$D. the patient could see $\frac{6}{6}$; and on trying $+5 \cdot 50$, no difference was noticed, but $+6$D. made the vision worse; so that $+5 \cdot 50$ was the correcting glass for the right eye.

On testing the left eye similarly, +5D. was the strongest lens that patient could tolerate. On trying both eyes together the patient could not bear the full correction, so it was reduced slightly, to enable him to see comfortably. The following prescription was given for constant wear, and patient was instructed to return in a couple of months, for the full correction to be given :—

R.E. +4·50
L.E. +4·00

Case 15.—Myopia. Miss L. L., age 24.

History.—This young lady said that she had "perfect sight for reading and sewing, but finds that she cannot recognise her friends, should they pass her across the road, and she thinks she needs glasses." The acuteness of vision of each eye separately is $\frac{6}{18}$. Even the weakest convex lens makes this line quite indistinct; hence the presence of Myopia is suspected.

A −1D. was found to make the vision much better; and, on increasing the strength, −3D. was found to be weakest that gave normal vision. The same result was obtained with the left eye.

Binocularly, the correction could be decreased by 0·50 without any serious impairment of vision; so the prescription for distance was :—

O.U. −2·50

the glasses to be worn for distance only.

Lenses were unnecessary for reading, as the patient could see more comfortably with the naked eye, at a distance of thirty-three centimetres.

Case 16.—Myopia. Mr. A. P. J. O., age 30.

History.—Book-keeper; used his eyes a great deal for near work. Complained that the eyes soon became fatigued, and that he could not see clearly at a distance.

The acuteness of vision of both eyes was found to be $\frac{6}{9}$, and the weakest plus lens made these letters blurred. -1D. brought vision up to $\frac{6}{6}$. A slightly stronger lens than this would also have given a vision of $\frac{6}{6}$; but in Myopia the rule is, to prescribe the weakest possible lens, otherwise the patient would be made artificially hypermetropic; so that we do not try to increase the correction above -1D. in this case.

As the left eye required the same lens, the following prescription was given for constant use.

O.U. -1D.

Case 17.—Simple Hypermetropic Astigmatism.

Master S. B. J., age 15.

History.—Complained of the eyes growing tired after reading. He had only noticed this of late, since he had been studying hard at school; and he could not read for long at a time. On looking intently at an object, patient turned his head on one side.

R.E. V. = $\frac{6}{9}$; no improvement with plus spheres, but vision was *not* made worse with a weak convex lens. As spherical lenses were of no use, Astigmatism was suspected, and patient told to look at the Astigmatic Dial. The lines appeared blackest in the horizontal meridian; so a weak convex cylinder was used, with the axis placed in the vertical. On increasing the power of the cylinder, a $+1$D. was found to render all the lines equally black. On the patient's attention being directed to the letters, he read $\frac{6}{6}$; so that $+1$D. cyl. ax. V. is the correction for the right eye.

L.E. V. = $\frac{6}{9}$; and the patient could just make out a few of the letters of the six-metre line. No sphere was accepted at all. On testing for Astigmatism, $+0{\cdot}75$ cyl. ax V. was found to be the correction; with which patient could read $\frac{6}{6}$ perfectly.

Prescription for Master S. B. J.:—

R.E. + 1 cyl. ax. V.
L.E. + 0·75 cyl. ax. V. } for constant use.

Binocularly, no spherical lenses would be accepted.

Case 18.—Compound Hypermetropic Astigmatism.

Miss McK., age 24.

History.—Was wearing

R.E. +2 cyl. ax. 80°
L.E. +0·5 cyl. ax. V.

constantly. This correction affords a visual acuity of $\frac{6}{30}$ with the right eye, and nearly $\frac{6}{12}$ with the left. Patient complains of headache and pain in the eyes, more especially in the right.

$$\text{R.E. V.} = \tfrac{6}{48}; \quad \text{L.E. V.} = \tfrac{6}{18}.$$

A weak plus sphere improves the vision of the right eye. The strongest that would be accepted was +1·25, which brought the vision up to $\frac{6}{36}$. On referring to the dial, the blackest lines appeared to be in the 140° meridian. On trying a weak convex cylinder, an improvement was noticed; so the strength of the cylinder was increased gradually to +2·50, which rendered all the lines equally black and distinct. With the above correction before the eye, patient could see $\frac{6}{9}$, which was the best vision obtainable with this eye.

The best spherical lens accepted by the left eye was +0·75; so this was discarded, and the test for Astigmatism begun. The patient saw blackest horizontally, so the correcting cylinder had to be placed axis vertical. +1 cyl. ax. V. was found to correct the Astigmatism; but when the patient looked at the letters again, she could not read more than $\frac{6}{9}$, so a weak plus spherical was placed behind the cylinder, and the strongest that gave best results was +0·75, which afforded a vision of $\frac{6}{6}$.

Prescription for Miss McK.:—

R.E. + 1·75 sph. $\bigcirc$ + 2·5 cyl. ax. 50°.
L.E. + 1·25 sph. $\bigcirc$ + 1 cyl. ax. V.

Binocularly, a + 0·50 sphere was accepted, which accounts for the difference between this prescription and the lenses first found necessary.

This patient returned about one month later, saying that the pains in her eye had completely disappeared, and that she could see beautifully with the glasses.

Case 19.—Compound Hypermetropic Astigmatism.

Miss M. I. B. S., age 18.

History.—This patient came simply because of her inability to see well, either near at hand or far away.

On testing the right eye, the visual acuity was $\frac{6}{36}$. A convex lens of 1D. improved vision slightly, and on increasing the power gradually, + 2·50D. was found to give best results, bringing vision up to $\frac{6}{18}$. On using + 3D., the patient could not see so well; so that the + 2·50D. was the strongest convex spherical that gave best vision. This lens was placed in the back cell of the trial frame, and then patient's attention was drawn to the dial. The lines appeared blackest in the horizontal, consequently the correcting cylinder should be placed in the vertical before the eye. + 1 cyl. ax. V. brought the vertical lines much darker, but not nearly so clear as in the horizontal. So a stronger one was tried, until + 2·50 cylinder was reached, which made the lines in the horizontal and vertical equally distinct; and, on slowly rotating the dial, it was ascertained that in all the other meridians the lines appeared equally black. This showed that the Astigmatism was corrected. With these glasses the patient read nearly $\frac{6}{6}$; no better result could be obtained.

The vision of the left eye was also $\frac{6}{36}$, which was improved mostly by a + 2·50 sphere, but with this lens it was not normal.

On testing for Astigmatism, the same correction was obtained as with the right eye—viz., + 2·50 cyl. ax. V.

When both eyes were being used, + 0·50 sphere was held before each eye, without any impairment of vision, so that + 0·75 was tried, but this made vision decidedly worse; + 0·50 sphere, then, was the most the correction could be increased by.

The following was prescribed to be worn constantly:—

O.U. + 3·00 sph. $\bigcirc$ + 2·50 cyl. ax. V.

Case 20.—Compound Hypermetropic Astigmatism; Accommodation very Active. Mr. McC., age 27.

History.—This patient was tested previously by Dr. ——, of Belfast, without relief. He complained of pain and watering of the eyes, and of constant headache; could not read for any length of time. The visual acuity of the right eye was $\frac{6}{9}$, and of the left, $\frac{6}{12}$. After considerable difficulty, the following correction was obtained:

R.E. + 0·75 cyl. ax. V.
L.E. – 0·5 sph. $\bigcirc$ + 1 cyl. ax. V.

with which the patient could see perfectly at a distance, and when reading.

As patient's answers were somewhat variable during the test, I thought it advisable that he should come again, and have this result confirmed before prescribing the glasses. So he was told to return in two days.

On the second test, the correcting lenses obtained were:—

R.E. + 0·25 sph. $\bigcirc$ + 1 cyl. ax. V.
L.E. + 0·75 cyl. ax. V.

—quite different from the first test; but they also afforded

a vision of $\frac{6}{6}$. Evidently the accommodation was playing practical jokes. This time a pair of + 1D. spheres were given to be worn constantly for a week, when the patient was to return again.

This third time of testing, the patient's answers were not so vacillating; the convex sphere having had the desired effect upon the accommodation; and the following correction was obtained:—

R.E. + 1·50 sph. ◯ + 1 cyl. ax. V.
L.E. + 0.50 sph. ◯ + 0·75 cyl. ax. V.

This last prescription was given for constant use. The patient returned in a fortnight, and said that the glasses were comfortable.

On reporting again, later, the glasses were still satisfactory, and I saw this patient only a few weeks back, when he also had a favourable report to make, and his headaches were not nearly of so frequent occurrence.

Case 21.—Simple Myopic Astigmatism.

Miss G. L., age 19.

History.—Dressmaker. Complains that she cannot see distinctly to do her work; and also that her eyes ache a great deal—she is also subject to headaches. Has never worn glasses before.

Visual acuity of right and left eyes, = $\frac{6}{36}$.

On testing the right eye, convex spheres made the vision worse, and on trying minus, no satisfactory answer could be obtained; they appeared to make the letters better, but smaller. Since both plus and minus spheres failed to improve vision, Astigmatism was suspected. On rotating the Astigmatic Dial slowly, patient said the lines were blackest in the vertical; and on rotating them to the horizontal, she could not see them at all. A plus cylinder, axis horizontal, was placed in the trial

frame (as no indication of what kind of cylinder was needed was obtained from the spherical lenses); but this made the Astigmatism more apparent, instead of correcting it, so that plus cylinders were evidently of no use.

A − 1D. cylinder was now placed before the eye, axis horizontal, instead of the convex; and with this the patient could just make out that there were some lines in the horizontal meridian; but could not count them. So the cylinder was increased to − 2D.; when on comparing the two directions on the chart, the vertical still appeared blacker than the other, although the patient could now count the lines in the horizontal. On placing a − 3D. in the trial frame, the patient declared that the lines were equally black in every direction; and on looking at the letters, could read $\frac{6}{9}$, but no better result was obtainable either by adding plus or minus spheres to the cylinders; in fact, any addition made the vision more blurred.

On the left eye being tested, the same result was obtained; and no alteration could be made when both eyes were used together.

Prescription for Miss G. L.:—

O.U. − 3 cyl. ax. H., for constant use.

These glasses were entirely satisfactory after patient had become used to them.

Case 22.—Compound Myopic Astigmatism.

Mrs. S. D., age 23.

History.—Complained of poor near and distant vision.

Patient sees with the right eye $\frac{6}{12}$, and with the left $\frac{6}{9}$ badly.

Testing the right eye first, a weak convex lens made the vision worse. The best spherical result obtained was

— 1·50D., which made the vision equal $\frac{6}{9}$. Since it was not possible to get a better result with spheres, Astigmatism was suspected.

On directing patient to the Astigmatic Dial, and rotating it, lines were seen blackest in the 100° meridian. Astigmatism being thus proved, a — 0·5 cylinder was placed before the sphere in the trial frame, axis 10°. When comparing the lines in the 100° and 10° meridian, the patient still saw them blackest in the 100° meridian. — 1D. cyl. ax. 10° was found to make the lines appear equally black in both directions. On directing patient's attention to the letters again, she was able to read $\frac{6}{6}$ easily.

The correction for the right eye was noted on paper :—

— 1·5 sph. $\bigcirc$ — 1 cyl. ax. 10°.

The weakest plus lenses were also rejected by the left eye; and the best result with spheres was — 0·75; which brought vision up to $\frac{6}{9}$ distinctly, while a few letters on the six-metre line could also be distinguished. The lens, being under 1D., was discarded; and patient's attention directed to the Astigmatic Chart.

The blackest lines on the dial were in the vertical; and — 0·50 cyl ax. H. was found to make these appear all alike. On directing patient to the letters, she could not quite see $\frac{6}{6}$; but on placing — 0·50 behind the cylinder, vision was made normal.

R.E. — 1·50 $\bigcirc$ — 1 ax. 10°.
L.E. — 0·50 $\bigcirc$ — 0·50 ax. H.

This correction was prescribed for constant use, as it was not possible to reduce the sphere at all, when testing both eyes together. Patient was able to read easily with these lenses, as well as to see at a distance in them.

Case 23.—Mixed Astigmatism. Mr. F. C., age 23.

History.—Patient stated that he has always suffered from poor vision; he has tried many spectacles, but has never been able to obtain any satisfactory correction.

Testing the right eye first, the visual acuity was noted, $\frac{6}{36}$; and on trying + 1D. sphere, it was found to impair the vision; and + 0·50 also made vision worse. So minus lenses were used; and upon gradually increasing the power, − 1·25 was the best correction obtainable with spheres. With this lens in the back cell of the trial frame, patient's attention was turned to the dial. The horizontal line was the only one which was seen at all distinctly. A − 0·50 cylinder was now placed in the front cell of trial frame, axis in the vertical; this, however, made the vision worse, and the Astigmatism more apparent than before. It was, therefore, discarded, and convex cylinders used in its place. + 1D. cyl. ax. V. was found to clear up the vertical lines fairly well; but they were not yet as clear as in the horizontal meridian, so this cylinder was removed, and a stronger one placed before the eye, until one was obtained which made the lines in both meridians equally black. In this case the Astigmatism was not corrected until a + 3·75 cylinder was used. With this, however, the lines all appeared equally distinct. When the patient returned to the letters, his visual acuity was still slightly below normal; so the sphere was increased in power, which improved the vision; an addition of − 0·25 being the lens that afforded a vision of $\frac{6}{6}$.

The correction for the right eye was:—

− 1·50 sph. ⊂⊃ + 3·75 cyl. ax. V.

This prescription does not require transposing, as it is already in the most desirable form.

The left eye, on being tested, required the same correction.

Prescription for Mr. F. C.:—

O.U. − 1·50 sph. ⊂⊃ + 3·75 cyl. ax. V. for constant use.

In order to make this case quite clear to the reader, we will illustrate it, showing exactly the effect of the different lenses used during the test.

The defect present is represented thus :—

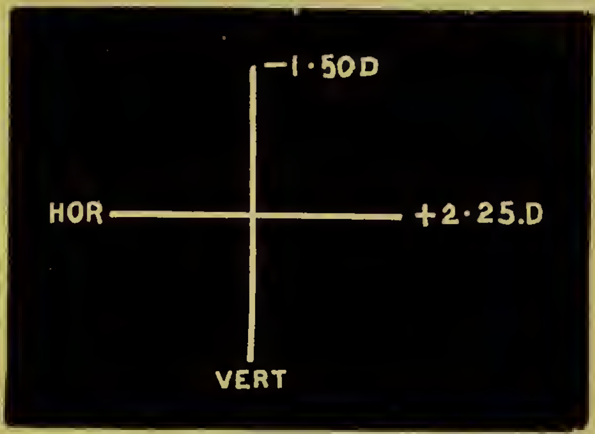


Fig. CXLII.

the vertical meridian being myopic 1·50D., and the horizontal hypermetropic 2·25D.

The + 1 sphere first tried naturally made the vision worse, as it changed the defect to this :—

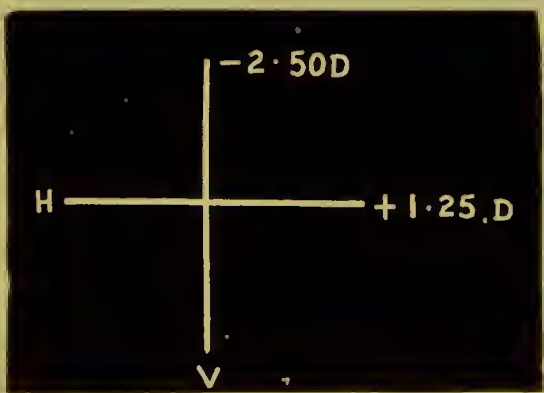


Fig. CXLIII.

But on holding a − 1·25 sphere before the eye, the vision

improved very materially, as the state of affairs was altered to this :—

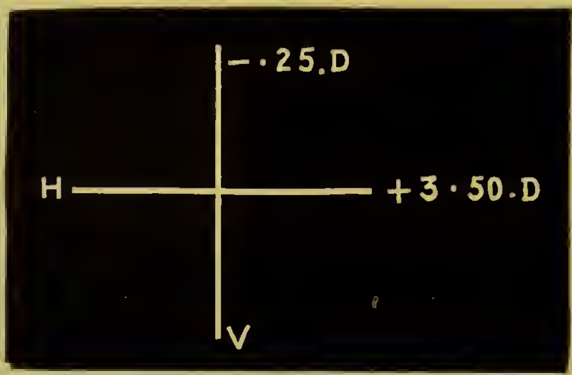


Fig. CXLIV.

This lens rendered one of the meridians practically normal, and made the other rather worse. The minus cylinder was rejected, as it made the hypermetropic meridian still worse, without altering the vertical meridian. The result of this lens is graphically :—

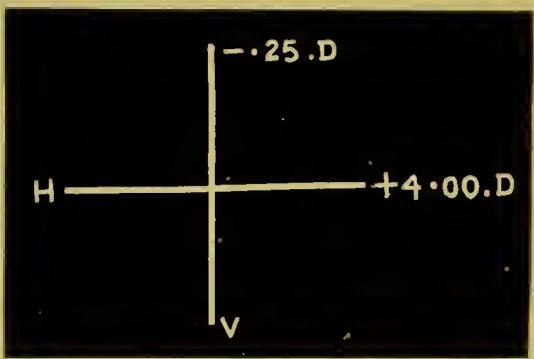


Fig. CXLV.

On changing to + 1 cyl. ax. V., the condition was altered for the better, thus :—

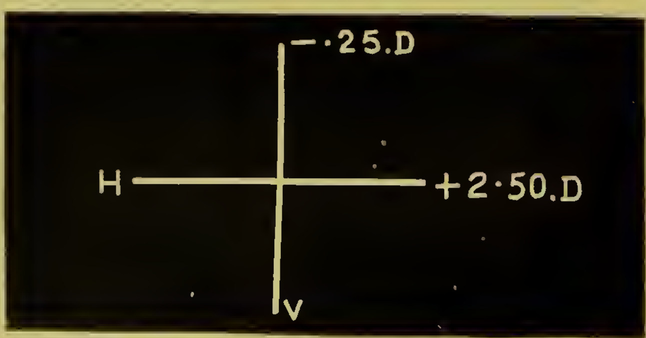


Fig. CXLVI.

and + 3·75 cyl. ax. V. entirely corrected the Astigmatism (by over-correcting the hypermetropic meridian, and making it slightly myopic). This left only − 0·25 sphere to be added to completely neutralize the patient's Ametropia.

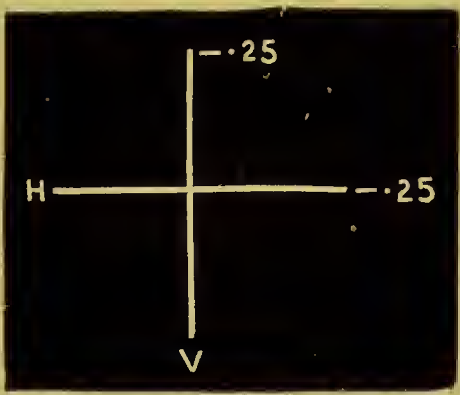


FIG. CXLVII.

Case 24.—SPASM OF ACCOMMODATION.

Master H. I. S. D., age 10.

History.—Patient complains of being short-sighted, and unable to see the blackboard at school. The eyes water a good deal; the pupils were rather small. In course of conversation, the boy's mother said he had only complained of his short-sightedness a little while.

On testing the distance vision, it was found to be $\frac{6}{24}$ with either eye. The weakest plus lens was rejected; and on trying minus, 1D. was found to improve the vision a good deal, and − 2D. brought it up to $\frac{6}{6}$ distinctly. The fact of a weak concave lens improving vision so much, and the data given above, suggested Spasm of Accommodation. On testing the near point without glasses in front of the eyes it was found to be nine centimetres, which at once proved the presence of spasm.

The patient's near point being nine centimetres indicated Hypermetropia of 3D. If patient was myopic to the extent of 2D., at his age the near point should have been 6·25 centimetres from the eyes.

+ 1·50 sphere was prescribed, to be worn constantly for a little while, and then patient was to return and report the result. Of course, the vision was made worse by the convex lens, but patient was warned of this, and told to persevere in the use of the glasses. When he returned, he had become accustomed to the lenses, and was able to accept a slightly stronger glass than previously. Eventually, the full correction was accepted.

Examples of Strabismus are unnecessary, as in these cases you correct the error of refraction present; and sufficient examples of the various forms of Ametropia have already been cited to give the reader a fair understanding of the method of procedure.

In some cases of mixed Astigmatism, no sphere will be accepted at all, in which case you at once turn to cylinders, using convex first, and then, if necessary, minus, placing them at right angles to the convex cylinder. In cases where no sphere is accepted, when on placing the cylinder in the trial frame at right angles to the direction of the blackest lines on the chart it is found to make the Astigmatism worse, rotate the axis of the cylinder to 90° from this position, when it will be found that one of the principal meridians will be improved. The other will require a cylinder of opposite power to make it appear distinct. If this is so, you treat each principal meridian separately, endeavouring to make each as clear as possible. When this is done, the Astigmatism will be corrected, and all the lines equally distinct. Of course, the cross cylindrical correction will have to be transposed into a sphero-cylindrical form.

GLOSSARY.

Aberration - -	Wandering from normal.
Abduction - -	Power of the External Recti.
Accommodation -	The act of adjusting the Crystalline Lens for near and far objects.
Achromatic - -	Without colour.
Achromatopsia - -	Inability to distinguish colours.
Adduction - - -	Power of the Internal Recti.
Albinism - - -	Abnormal deficiency of pigment in Iris and Choroid.
Amaurosis - - -	Blindness without any visible cause.
Amblyopia - -	Indistinct vision. (See Amaurosis.)
Ametropia - - -	A defective condition of the refracting system of the eye.
Amplitude (of accommodation) - -	Power or extent.
Anæmia - - -	Deficiency of blood.
Anæsthesia - -	Loss of Sensation.
Anchyloblepharon -	Stiffening of the eyelids.
Anisometropia - -	Unequal refraction of the two eyes.
Anopsia - - -	Without vision.
Antimetropia - -	A difference in refraction of the two eyes, as regards kind.
Aphakia - - -	The condition of the eye after the removal of the lens.
Aplanatic - - -	Free from aberration.

Arcus senilis - -	An opaque circle round the margin of the Cornea, depending upon fatty degeneration.
Asthenopia - -	Weakness of the ocular nerves.
Astigmatism - -	Not a point. An inequality of the Refractive Media of the eye.
Bi-focal - - -	Having two foci.
Binocular vision -	Faculty of using the two eyes harmoniously.
Blepharitis - -	Inflammation of the eyelids.
Bouphthalmia - -	The first stage of Hydrophthalmia.
Brachymetropia -	Short sight.
Canthus - - -	Angle of the eyelids.
Cataphoria - -	Insufficiency of the Superior Rectus.
Cataract - - -	An opacity of the Crystalline Lens, or of its capsule, or both.
Catoptrics - - -	Science of reflected vision.
Chalazion - - -	A small tumour in the substance of the eyelid.
Chemosis - - -	Swelling of the Ocular Conjunctiva.
Chiasma - - -	The point of decussation of the optic nerves.
Choroiditis - -	Inflammation of the choroid.
Chromatism - -	Coloration.
Cilia - - - -	Eyelashes.
Coloboma - - -	Mutilation.
Concentric - -	Having a common centre.
Concomitant - -	Accompanying.
Conjugate - - -	Joined together.
Conjunctivitis - -	Inflammation of the conjunctiva.
Converge - - -	To tend towards a common point.
Cyclitis - - -	Inflammation of the Ciliary body.
Cycloplegia - -	Paralysis of the Ciliary muscle.

Cycloplegic - -	A drug which temporarily paralyses the accommodation.
Daltonism - - -	Colour-blindness.
Deorsumduction -	Power of the Inferior Rectus and Superior Oblique.
Dioptre - - -	(To see through). The unit of measurement now almost universally used for expressing the focal length of lenses.
Diplopia - - -	Double vision.
Diverge - - -	To tend from a point in various directions.
Dynamic - - -	Force.
Ecchymosis - -	A pouring out of blood into tissues.
Emmetropia - -	A natural condition of the refracting system of the eye.
Entoptic - - -	Within the eye.
Enucleate - - -	To remove.
Epiphoria - - -	Undue secretion of tears.
Esophoria - - -	Insufficiency of the External Recti.
Exophoria - - -	Insufficiency of the Internal Recti.
Exophthalmia - -	Protrusion of the globe of the eye between the lids, so that they cannot cover it.
Extra-ocular - -	Outside the eye.
Far point - - -	Furthest reading distance.
Focus - - -	The point to which rays of light converge, or from which they diverge, after refraction or reflection.
Fovea centralis - -	A dark red spot observable in the centre of the Macula Lutea. The thinnest part of the Retina.
Fundus (of the Eye) -	The posterior inner surface of the eye.

Glaucoma - - -	(Greenness). It denotes a morbidly increased tension of the coats of the eye, produced by intra-ocular pressure of its fluids.
Hemeralopia - -	Night-blindness; but the vision is comparatively good by day.
Hemianopsia - -	Loss of vision in half the field.
Heterophoria - -	Abnormal balance of the muscles.
Heterotropia - -	Out of place, or squint.
Hordeolum - -	Stye.
Horopter - - -	A line connecting all those points in the visual field which are projected on to corresponding parts of the two Retinæ.
Hyaloid - - -	A glass-like membrane which encloses the Vitreous.
Hyaloiditis - -	Inflammation of the Hyaloid Membrane and of the Vitreous Humour.
Hyperæmia - -	The condition of the blood above normal.
Hyperæsthesia - -	Over-sensitiveness.
Hypermetropia - -	Over-sight.
Hyperopia - - -	(See Hypermetropia).
Hyperphoria - -	Insufficiency of the Inferior Rectus.
Hypopyon - - -	A collection of pus in the anterior chamber of the eye.
Infraduction - -	A movement of the eyeball downwards.
Intra-ocular - -	Inside the eye.
Iridectomy - -	The operation of cutting off a portion of the free edge of the Iris, for the formation of an artificial pupil.
Iridodonesis - -	Quivering Iris.
Iris - - - -	A rainbow. The coloured circular structure extending across the globe of the eye, separating the anterior from the posterior chamber.

Iritis - - - -	Inflammation of the Iris.
Keratitis - - -	Inflammation of the Cornea.
Keratokonus - -	Conical shape of the Cornea.
Lachrymation - -	Over-flow of tears.
Lagophthalmos - -	A shortening of the upper lid.
Lamina cribrosa -	The weakest part of the Sclerotic, which is at the entrance of the Optic nerve.
Leucoma - - -	White opacities of the Cornea.
Longissimus oculi -	The name given to the Superior Oblique, as it is the longest muscle of the eye.
Macula Lutea - -	The yellow spot; that part of the Retina which lies directly in the axis of vision.
Meibomian glands -	Glands situated on the inner surface of the eyelids.
Metamorphopsia -	The seeing objects distorted.
Metrology - - -	A discourse on the measurement of the eye.
Migraine - - -	Sick Headache.
Monocular vision -	The using only one eye at a time.
Muscæ volitantes -	Small spots which float on the field of vision.
Mydriasis - - -	Unnatural dilatation of the pupil.
Mydriatic - - -	A drug which temporarily dilates the pupil.
Myopia - - -	To close the eyes.
Myosis - - -	Unnatural contraction of the pupil.
Myotic - - -	A drug which stimulates the Sphincter muscle into action.
Myxoma - - -	A tumour consisting generally of mucous. (See Chalazion.)

Nebula	A cloud. A slight form of opacity of the Cornea.
Neuritis	Inflammation of a nerve.
Nictitation	Winking.
Nyctalopia	Day-blindness or night vision.
Nystagmus	An involuntary oscillation of the eye-balls, common amongst miners.
Œdema	(Literally). A swelling of any kind.
Ophthalgia	Pain in the eye.
Ophthalmia	Inflammation of the eyes.
Ophthalmography	A description of the eye.
Ophthalmoplegia	Paralysis of one or more muscles of the eye.
Optics	The science of light and vision.
Optic Axis	Imaginary line connecting the geometrical centres of the Cornea and Retina.
Orbit	The bony cavity in which the eyeball rests.
Orthophoria	Natural equilibrium of the muscles.
Orthotropia	Straight; opposite to Heterotropia.
Palpebræ	The eyelids.
Pannus	A vascularisation of the Cornea.
Papilla	The optic disc.
Papillitis	Inflammation of the optic disc.
Parallax	The apparent displacement of an object observed, resulting from displacement of observer.
Periscopic	To look around.
Phakatis	Inflammation of the Crystalline Lens.
Phorometry	Testing of the extra-ocular muscles.
Photometry	A method of estimating the relative intensities of light.

Photophobia - -	Intolerance of light.
Photopsia - - -	The subjective sensation of a bright light.
Pinguecula - -	A small yellow elevation of the conjunctiva, close to the inner or outer margin of the Cornea; seen generally in elderly persons.
Polyopia - - -	Multiple vision.
Posterior staphyloma -	A backward protrusion of the eyeball.
Presbyopia - -	Aged sight; failure of vision when directed to near objects.
Prismosphere - -	A prism having a spherical curvature.
Proptosis - - -	Protrusion of the globe of the eye.
Pterygium - -	A triangular thickening of the conjunctiva.
Ptosis - - -	A falling of the upper lid.
Pupilloscopy - -	The shadow test.
Pupilometer - -	An instrument for measuring the pupil.
Retina - - -	A net-like expansion of the Optic nerve.
Retinitis - - -	Inflammation of the Retina.
Sclerosis - - -	Hardness.
Sclerotic - - -	(Hard). The white of the eye.
Scotoma - - -	A fixed dark spot.
Staphyloma - -	A protrusion.
Static - - -	Natural.
Stenopaic - - -	Having a narrow opening.
Stigma - - -	A point.
Stigmatism - -	Definite vision.
Strabismus - -	Squinting; a condition in which the optic axes of the eyes are not directed to the same object.
Supercilia - - -	Eyebrows.
Supraduction - -	A movement of the eyeball upwards.

Sursumduction - -	Power of the Superior Rectus and Inferior Oblique.
Symmetrical point -	Used by some authorities in place of the term, "secondary focus."
Tarsal - - -	Belonging to the eyelid.
Tinea tarsi - -	Eczema of the eyelids.
Trachoma - - -	A form of granular conjunctivitis.
Tutamina - - -	Protections, defences.
Vascular - - -	Relating to vessels.
Visual Angle - -	The angle formed by the crossing of two rays proceeding from opposite points of any body, in their passage through the pupil of the eye.
Visual Axis - -	A line drawn from the yellow spot of the Retina to the Cornea, in the direction of the object looked at.
Vitreous - - -	A transparent fluid of semi-gelatinous substance, constituting about $\frac{5}{6}$ths of the bulk of the globe of the eye.
Xerophthalmia - -	A dryness of the eye, from a deficiency of the mucous secretion of the Conjunctiva.
Yellow spot - -	Most sensitive point of the Retina to light.
Zonule of Zinn - -	Suspensory Ligament of the Crystalline Lens.

PREFIXES AND SUFFIXES.

A collection of Prefixes and Suffixes, and their meanings, with words illustrating their use.

PREFIXES.

A-, am-, or an- - - the same as im-, in-, or un-, a prefix used in a negative sense, *e.g.*, achromatic (without colour), anodyne (without pain), anencephalia (brainlessness).

Ab- (*Lat.*) - - - from, separating. Before C and T, it is changed into abs-, *e.g.*, abscess, abstinence.

Amph-, amphi- (*Gr.*) - about, around, on both sides, *e.g.*, amphibious (having the faculty of living in two elements).

An-, ana- (*Gr.*) - - upwards, throughout, again, *e.g.*, anaplasty (a forming again; a restoration of lost parts).

Ant-, anti- (*Gr.*) - - against, signifying opposition, *e.g.*, antacid, antipathy, antidote, etc.

Apo- (*Gr.*) - - away from, off, denoting sometimes a separation, as in apo-physis (a process of a bone).

Aut-, auto- (*Gr.*)	self (a reflex pronoun), *e.g.*, autoplasty (formed from oneself), autobiography, etc.
Bi- (*Lat.*)	two, double, *e.g.*, bi-lateral (two sides), bi-axial, bi-concave, etc.
Bou-	Greek particle, used sometimes to express something *huge* or *large*, *e.g.*, Bouphthalmia or Buphthalmia.
Cat-, cata-, cath- (*Gr.*)	down, against, into; sometimes denotes thoroughly; *e.g.*, cataphoria (a downward tendency).
Com-, con- (*Lat. cum.*)	with, to, against; *e.g.*, compression, contact.
Contra- (*Lat.*)	against, in opposition to; *e.g.*, contradict; sometimes abbreviated *con.*; *e.g.*, pro. and con. (for and against).
De- (*Lat.*)	meaning (1) down, away, off; *e.g.*, deglutition (the act of swallowing). (2) deficiency, *e.g.*, decoloration.
Demi- (*Fr.*)	half; corresponds to the Gr. hemi-, and Lat. semi-.
Di- (*Gr.*)	a numerical adverb used as prefix, signifying twice, double, etc., *e.g.*, dichotomus (cut in twain), dimorphic (having two distinct forms).
Dia- (*Gr.*)	through; *e.g.*, diagnosis (a knowing through, that is, thoroughly, of a disease).
Diplo- (*Gr.*) Duplo- (*Lat.*)	signifies twofold; *e.g.*, diplopia, duplocarburet.
Dys- (*Gr.*)	corresponds to *dis-*, *mis-*, *ill-*, *un-*; also indicates difficulty, hard, unlucky; *e.g.*, dyschroia (discoloration), dyschromatopsia (difficulty in distinguishing different colours), dysphonia (defective voice).

Ec-, ecto-, ex- (*Gr.*) -	out, out from, outside; *e.g.*, ectropion (a turning out of the eyelid); exophthalmia (protrusion of the eyeball).
Em-, en- (*Gr.*) - -	in, within; *e.g.*, emmetropic; endermic (in the skin).
Endo-, ento- (*Gr.*) -	within; *e.g.*, endoscope (an instrument for exploring internal organs).
Ep-, eph-, epi- (*Gr.*) -	on, upon, over; *e.g.*, epicanthus. Sometimes conveying the idea of increase or repetition; *e.g.*, epidemic.
Eu- (*Gr.*) - - -	opposite to "dys"; signifying well, easy, good; *e.g.*, euphonic (having an agreeable sound); euonymous (lit. "well named").
Extra- (*Lat.*) - -	above, over, outside; *e.g.*, extra-ocular.
Exo- (*Gr.*) - - -	outward; *e.g.*, exophoria.
Gastr-, gastero-, gastro- (*Gr.*) - - -	denotes the stomach; *e.g.*, gastralgia (pain in the stomach).
Haema-, haemo-, haemato- (*Gr.*) -	blood; *e.g.*, hæmal (relating to the blood); haematology (history of the blood).
Hemi- (*Gr.*) - -	half; *e.g.*, hemianopsia.
Hetero- (*Gr.*) - -	denoting a difference; *e.g.*, heteropathy (art of curing, founded on differences); abnormal; *e.g.*, heterophoria.
Hydro- (*Gr.*) - -	water; *e.g.*, hydrometer.
Hygro- (*Gr.*) - -	moisture; *e.g.*, hygrometry.
Hyper- (*Gr.*) - -	over, above, beyond, excess of; *e.g.*, hypermetropia, hypertrophy.
Hyp-, Hyph-, hypo- (*Gr.*) - - -	below, under; sometimes denoting a deficiency; *e.g.*, hypodermic; hypoplasia (deficient development of an organ).

Im-, in- (*Lat.*) - -	like the English "un"; *e.g.*, inconsistent; sometimes signifying within, into; *e.g.*, incision.
Infra- (*Lat.*) - -	beneath; *e.g.*, infraduction.
Inter- (*Lat.*) - -	among, between; *e.g.*, intermediate, interlude, etc.
Intra (*Lat.*) - -	within, inside; *e.g.*, intra-ocular.
Iso- (*Gr.*) - - -	denotes equality or similarity; *e.g.*, isochromatic, iso-thermal.
Leuco- (*Gr.*) - -	white; *e.g.*, leucoma.
Litho- (*Gr.*) - -	stone; *e.g.*, lithograph.
Macro- (*Gr.*) - -	large; *e.g.*, macroscopic (opposite to microscopic).
Melano- (*Gr.*) - -	pigment, black; *e.g.*, melanoderma (black discoloration of the skin).
Mes-, meso- (*Gr.*) -	middle, between; *e.g.*, mesoderm.
Meth-, meta- (*Gr.*) -	after, with, amidst. In composition it denotes change, transference; *e.g.*, metamorphosis (a change of form).
Micro- (*Gr.*) - -	small; *e.g.*, microscopical.
Mon-, mono- (*Gr.*) -	single, denoting unity; *e.g.*, monocle.
Myo- (*Gr.*) - - -	muscle; *e.g.*, myotomy (dissection of the muscles).
Myo- (*Gr.*) - - -	to close; *e.g.*, Myopia.
Neur-, neuro- (*Gr.*) -	relating to a nerve or nerves; *e.g.*, neuritis (inflammation of the nerves).
Odonto- (*Gr.*) - -	relating to the teeth; *e.g.*, odontalgia (toothache).
Oligo- (*Gr.*) - -	little, few, lack of; *e.g.*, oligo-hæmia (deficiency of blood).
Ophthalmo- (*Gr.*) -	the eye; *e.g.*, ophthalmoplegia (paralysis of one of the muscles of the eye).
Ortho- (*Gr.*) - -	straight; *e.g.*, orthophoria.
Osteo- (*Gr.*) - -	Bone; *e.g.*, osteology (a treatise of the bones).

Oxy- (*Gr.*) - - -	acidity, oxygen. Sometimes denoting acuteness of sense; *e.g.*, oxyopia (acuteness of sight).
Pan-, Pant- (*Gr.*) -	all, every; *e.g.*, pantoscopic; pantophobia (fear of all things); panacea (a "cure-all").
Par-, Para- (*Gr.*) -	through, near, about; *e.g.*, paracentesis (a piercing through).
Per- (*Lat.*) - - -	through; *e.g.*, perforation.
Peri- (*Gr.*) - - -	about, around; *e.g.*, periscopic.
Pol-, Poly- (*Gr.*) -	many, much; *e.g.*, polyopia, polygon (a figure of many angles).
Presbys- (*Gr.*) - -	old; *e.g.*, presbyopia.
Pro- (*Gr.*) - - -	before, forward; *e.g.*, prognosis (a knowing beforehand the termination of a disease).
Pseudo- (*Gr.*) - -	false, counterfeit; *e.g.*, pseudonym.
Pyo- (*Gr.*) - - -	pus, matter; *e.g.*, pyogenesis (formation of pus).
Pyr-, Pyro- (*Gr.*) -	fire, fever, heat; *e.g.*, pyrometer (an instrument for measuring high temperatures).
Quadri- (*Lat.*) - -	four; *e.g.*, quadrilateral (having four sides).
Retro- (*Lat.*) - -	backward, behind; *e.g.*, retrospect.
Semi- (*Lat.*) - -	half; *e.g.*, semi-circle. Sometimes signifying imperfect; *e.g.*, semi-opaque.
Sub- (*Lat.*) - - -	under, beneath, below; *e.g.*, sub-ærial.
Super-, supra- (*Lat.*) -	above, over, excess; *e.g.*, supercilium (the eye-brow), superabundance, supraduction.
Syn-, sym-, sy- (*Gr.*) -	with, together, union; *e.g.*, sympathy, synchronous (happening at the same time), system.

SUFFIXES.

-aceous (*Gr.*) - -	termination denoting a resemblance to a substance; *e.g.*, membranaceous (resembling a membrane). (See "ous.")
-æmia,-hæmia - -	is used to form compound words denoting that the substance indicated by the original word is in the blood, or denotes the character of the blood; *e.g.*, hydræmia (watery blood).
-agogue (*Gr.*) - -	denotes substances which expel others; *e.g.*, hydragogue (remedy to carry water from the system).
-agra (*Gr.*) - - -	seizure or attack (usually sudden); *e.g.*, ophthalmagra (pain in the eye), podagra (gout in the foot).
-algia (*Gr.*) - -	pain; *e.g.*, neuralgia (pain in a nerve); odontalgia (toothache).
-cele (*Gr.*) - - -	protrusion, tumour; denotes particularly that of hernia; *e.g.*, buboncele (hernia of the groin); ophthalmocele (extraordinary protrusion of the eye).
-colla (*Gr.*) - -	glue; *e.g.*, icthyo-colla (fish-glue or isinglass).
-ectomy (*Gr.*) - -	denotes removal, cutting out; *e.g.*, corectomy (cutting out part of the iris), ophthalmectomy (removal of the eyeball).
-form (*Gr.*) - - -	likeness, resemblance; *e.g.*, ensiform (swordlike).
-graphy (*Gr.*) - -	writing, painting, description; *e.g.*, lithography, nosography (a description of diseases).

-itis (*Gr.*) - - -	inflammation; *e.g.*, blepharitis, keratitis, ophthalmitis, etc.
-logy (*Gr.*) - - -	treatise, description; *e.g.*, biology; physiology (description of the functions of the body).
-lysis (*Gr.*) - - -	denoting separation, resolution; *e.g.*, analysis.
-ma (*Gr.*) - - -	termination which makes an adjective or verb into a noun; *e.g.*, glaucoma (a diseased condition causing) greenness (glaucos = green).
-malacia (*Gr.*) - -	denotes softening; *e.g.*, keratomalacia (softening of the Cornea).
-mania (*Gr.*) - -	madness; *e.g.*, dipsomania (insanity, with excessive thirst for alcohol); kleptomania, etc.
-meter (*Gr.*) - -	measure *e.g.*, barometer (measure of weight).
-odes (*Gr.*) - - -	fulness. Denotes fulness of something expressed in former part of word; *e.g.*, hæmatodes (fulness of blood).
-odynia (*Gr.*) - -	pain; *e.g.*, gastrodynia (pain in the stomach); ophthalmodynia (pain in eye).
-oid (*Gr.*) - - -	likeness; *e.g.*, adenoid (gland-like); choroid (leather-like).
-opia, -ops, -opsia (*Gr.*) -	Relating to the eye and vision; *e.g.*, ametropia, photopsia, myopia, etc.
-ous - - - -	denotes quality; *e.g.*, membranous (belonging to membrane). (See "aceous").
-pathy (*Gr.*) - -	denoting an affection or disease; *e.g.*, sympathy (fellow-feeling); neuropathy (a diseased condition of the nervous system). It sometimes denotes a system of treatment; *e.g.*, electropathy (cure by use of electricity).

-phobia (*Gr.*) - -	fear; *e.g.*, photophobia.
-phoros (*Gr.*) - -	signifying a tendency; *e.g.*, heterophoria (a tendency to deviation).
-plasty (*Gr.*) - -	denotes an artificial formation; *e.g.*, keratoplasty (operation of restoring the Cornea); blepharoplasty (restoration of eyelid).
-rhaphy (*Gr.*) - -	a suture or seam; *e.g.*, neurorrhaphy (suturing a nerve).
-rhagia (*Gr.*) - -	denoting a bursting forth; *e.g.*, hæmorrhagia (the bursting forth of blood).
-rhœa (*Gr.*) - -	a discharge, flow; *e.g.*, hydrorrhœa (watery discharge). It sometimes denotes an abnormal flow of mucus (catarrh); *e.g.*, ophthalmorrhœa (catarrh of the eye).
-scopy (*Gr.*) - -	examination; *e.g.*, ophthalmoscopy.
-sis (*Gr.*) - -	a termination denoting a cause, action, or process; *e.g.*, amaurosis (a darkening, blindness); glaucosis (cause of glaucoma).
-tomy - - -	to cut, signifying an incision; *e.g.*, tenotomy, keratotomy.
-tropos - - -	a turning; *e.g.*, heterotropia (an actual deviation or squint).

INDEX.